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STRENGTH AND WEAR OF RAI[LS]

AND

THEIR INFLUENCE ON THE SELECTION OF THE MOST ECONOMICAL SECTION.

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I. INTRODUCTION.

1. When dealing with proposals for renewals of rails in the track, two questions have to be considered, viz., whether the existing rails require renewal and what would be the most economical section to use for renewal. The latter question has to be considered also when the selection of the section of rail to be used in a new line of railway is under consideration.

2. No attempt appears to have been made in the past to fix any limiting strengths for old worn rails,* although the most suitable sections of new rails, for various maximum axle-loads, have been prescribed from time to time. The selection of these suitable sections has been based on the results of experience and of observation of the behaviour of rails in the track: that is to say, on practice and not on theory. Decisions, as to whether existing rails require renewal, have also been based usually on rough running and difficulty in good maintenance, due either to the age of the rails or to the use of heavier axle-loads.

3. Although, therefore, it has been accepted generally that new rails of certain minimum sections should be used for certain maximum axle-loads, no definite or uniform ideas or orders have existed as to when those rails should be considered to be unfit for further service in the main line. As a result of this state of affairs, the "minimum weight of rail per yard," prescribed by the Railway Board for each axle-load, in the "Schedule of Maximum, Minimum and Recommended Dimensions" for Indian Railways, is not the "minimum" in the correct sense of the word. It does not mean that, when a rail is worn down the least fraction belo[w]

minimum weight per yard, it must be renewed in the interests of safety but it means that, when new rails are to be laid in the track, they should not be below a certain weight, which includes ample margin for permissible wear before the rails will need to be renewed again. That item in the "Schedule of Dimensions" is, therefore, a "recommended" rather than a "minimum" dimension and a more definite standard of the limit of strength of worn rails is desirable.

4. Considering the second question, regarding the most economical section to use for renewal, it will be admitted that the probable life of the new rail is the most important factor that will help in determining the most economical section. As the probable life will depend chiefly on the rate of wear and as the rate of wear depends, under ordinary conditions on a straight road and ignoring any question of the quality or hardness of the steel, on the gross tonnage per annum that is carried by the track, it is evident that the probable life of any section of rail will depend on the volume of traffic carried by the railway, in which it is to be laid, and will not be as much on a main line as on an unimportant branch line. The probable life will also depend on the permissible limit of wear before the rail must be renewed; that is to say, if the probable annual rate of wear is 0·2 lbs. per yd., the probable life will be determined by the number of lbs. per yard that may be worn away before renewal becomes necessary.

5. The solutions of both the questions, referred to in para 1, will depend, as has been shown, on the limit of strength of worn rails and there have been in the past no rules or data available to fix that limit. The writer has, therefore, attempted to make use of such other data, as he has found available, in investigating the problem with a view to arriving at a practical solution. The first fact, that was brought to notice, was that old type 75 lbs. D.H. rails, which proved to be no longer fit for use in the main line under 17 ton engine axle-loads at unrestricted speeds, were found to have been worn down to an average weight of about 72·76 lbs. per yard, with a resulting average "section modulus" of about 7·9. The conclusion arrived at was that the maximum driving-wheel axle load in tons, which a rail could efficiently carry at unrestricted speeds, was about 2·25 times the section modulus of the rail-section, which agrees more or less with the tabulated statement of worn rails, showing their moments of resistance and maximum axle-loads carried, to be found in the Chapter on "Permanent Way" in "Light Railway Construction," by R. M. Parkinson.

6. It was necessary to confirm this "empirical" conclusion by "theory" and the track had to be considered for this purpose

both as a rigid structure, when the sleepers are laid direct on steel girders, and also as an elastic structure, when the track is supported on an ample depth of good well packed ballast. As the stiffness of rails, weighing 60 lbs. per yard and over, is ample, if their strength is sufficient, and as it is these heavier rails, which are used on lines with fast heavy traffic requiring ample stiffness of track, the question of stiffness has been ignored in the investigations, the results of which are embodied in this paper. It is true that the stiffness of rails, lighter than 60 lbs. per yard, falls away rapidly, compared with the strength, as the weight per yard is reduced. These lighter rails, however, are not likely to be used except in Metre Gauge or Narrow Gauge lines, on which the maximum running speeds of trains are not likely to be as high as 60 miles per hour. In fact the lighter the rail, the lower probable maximum running speed will be on the line, on which it is likely to be used, and it may safely be assumed that the maximum speed on metre gauge railways will not exceed 40 miles per hour and that on narrow gauge railways it will be as low as 25, or even 20, miles per hour. For this reason, it is considered that stiffness in rails, lighter than 60 lbs. per yard, is not of the same importance as for the heavier sections of rail and that the maximum permissible axle loads may be taken as 2¼ times the section modulus for these lighter rails also.

II. LIMIT OF STRENGTH.

1. In considering the maximum strain, which a rail may be subjected to by a certain driving wheel axle load at unrestricted speeds, allowance must be made for the following factors in addition to half the dead weight of the axle load :—

(*a*) Effect of oscillation and concussion, which momentarily throws more than half the axle load on to each wheel.

(*b*) Hammer action of counterweights on the driving-wheels, which are usually those having the maximum axle-load.

(*c*) Impact due to sudden application of the moving load.

The worst effect on the rail occurs when (*a*) (*b*) and (*c*) happen to coincide and this maximum effect must be considered, when considering the minimum strength of rail, that may be used under any given axle-load, treating the track as a rigid structure when the sleepers are laid direct on steel girders.

2. The absolute value of a factor that will cover (*a*) is impossible to calculate but Trautwine, under "Friction," gives the results of an experiment made by Wellington, with loaded freight cars at speeds varying from 0 to 35 miles per hour, to arrive at the

values of car resistance at various speeds. In the results obtained the resistances, due to (1) axle, tyre and flange, (2) oscillation and concussion and (3) air resistance, were separated. According to Trautwine also, the coefficient of friction is independent of the area of surface in contact and in the case of kinetic friction the coefficient is independent of the velocity. In other words the frictional resistance depends solely on the total pressure or weight at all velocities. The results of Wellington's experiment proved that the resistance due to (2) was negligible at 10 miles per hour but at 30 miles per hour (2) was approximately equaly to (1) and at 20 miles per hour it was about half what it was at 30 miles per hour. As 30 miles per hour is about the maximum speed for M. G. trains, and the minimum speed for B. G. mail trains, that is a suitable speed to consider in connection with strength of rails on B. G. and M. G. main lines for unrestricted speeds. The increased resistance due to oscillation and concussion is partly due to increased weight thrown on to the bearing surface, resulting in increased friction, and partly due to the resulting increase of wave motion in the track, which compels the wheels to continually climb up a grade on to the higher portion of the rail head. It is impossible to separate these two portions of the increased resistance accurately but they may roughly be taken as one third due to extra weight thrown on the bearings and two thirds due to wave motion. We may, therefore, take the maximum additional pressure on the rail, due to oscillation and concussion at unrestricted speeds, at one third the static wheel-load.

3. The absolute value of (*b*) is also difficult to calculate but it is far from negligible. It has been found by experiment that, if the driving-wheels are balanced so as to counteract horizontally the full weight of the reciprocating parts, the effect on the pressure between wheel and rail is so great as to cause the driving-wheels to leave the rail at high speeds, when the counterweights are up, and to progress in a series of bounds. A fully horizontally balanced driving-wheel, therefore, produces an effect on the rail equal at least to the static wheel-load. If the driving wheels are fully balanced vertically on the other hand, so that the rail barely suffers at all, the vibrations in the locomotive frame and body are excessive. In counterbalancing driving-wheels, therefore, the golden mean is aimed at but even that gives a great momentary excess, over the static wheel-load, of the pressure on the rail, which may be taken as about a third of the static wheel-load for a well-balanced locomotive.

4. To allow for (*c*), if the static weight on a wheel is suddenly applied to a short span of about 2 ft. of rail, the impact factor, by which it must be multiplied in order to obtain the necessary additional allowance for impact, is about 1·33 according to the latest

Bridge Rules. This would, however, give a total load of more than double the static load; but, as hammer action of counterweights and lurching of the locomotive have been allowed for separately, the allowance for impact may be taken as only double the static load, which is the theoretical maximum for a load suddenly applied. The total maximum load, which a rail has to carry, is therefore

$$W = \frac{A}{2}(\cdot 33 + \cdot 33 + 2)$$

$$= \frac{A}{2} \times 2{\cdot}66, \text{ where } A = \text{ the maximum axle-load.}$$

5. Taking the most favourable conditions, under which a rail may be called upon to bear this load, so as to allow for any tendency in paras 2, 3, and 4 to overestimate the value of the total load, we may consider the rail as a girder, fixed at both ends and supported on full width sleepers, so well fitted on the girders that they do not sink or tilt. Considering the case of a flat-footed rail resting on a sleeper 10″ wide, as the maximum permissible spacing of sleepers on girders in the case of Broad Guage track is 2′ 6″ centres, the effective span of rail may be taken as 26·66″, *i. e.* one third of the widths of the bearings plus the clear span, as is done in the case of girders with ordinary fixed bearing plates. In such a case $M = \frac{Wl}{8}$, where M = moment of resistance in inch tons and l = effective span in inches

$$\text{or } 10 \times X = \frac{A}{2} \times 2{\cdot}66 \times \frac{26{\cdot}66}{8}$$

$$\text{or } A = X \times \frac{10 \times 2 \times 8}{2{\cdot}66 \times 26{\cdot}66} = 2{\cdot}25X \text{ approximately.}$$

Where X is the minimum section modulus of a rail to carry an axle load of A tons, and 10 tons per sq. inch is the maximum permissible working stress in the steel.

The limit of safety, therefore, appears to be when the section modulus of the rail is equal to four-ninths of the driving-wheel axle-load, or eight ninths of the wheel-load in tons, which agrees with the empirical conclusion, referred to in para. 5 of Chapter I.

6. This result has also been verified for track treated as an elastic structure, as detailed in the following paras., on the lines of the investigations carried out and results obtained in *America, *vide* Proceedings of the American Society of Civil Engineers, January 1918, pages 58-247, relevant extracts from which will be found in Appendix I. None of the track tested in America coincides with worn 75 lbs. rails and Indian spacing and size of sleepers, but the nearest to this is 85 lbs. worn rails with 6 to 12 inches of ballast under the sleepers and the results, obtained on

that track with a " Mikado " type locomotive, have been adopted in these calculations, where necessary.

7. Paras. 5 and 6 of the extracts in Appendix I, contain formulæ for a single static load and the method of modifying the results obtained from them, so as to allow for a series of loads. That these formulæ give results closely approximating to actuals was verified by the tests made subsequently. The greatest Bending Moment is usually to be found under the leading driver and this has been selected as the wheel to be considered in this connection. The value of 'u', the modulus of elasticity of rail-support, has been taken as 900 lbs. per inch, somewhat less than for the American 85 lbs. track, vide para 47 in Appendix I. The rail considered is an old type 75 lbs. D. H. rail worn down to about 72·76 lbs., with a Moment of Inertia of 20·35 and Section Modulus of 7·9.

8. According to an equation in para. 5 Appendix I, the maximum bending moment under a static load, representing a single axle-load, is $M_0 = P \sqrt[4]{\frac{E.I.}{64u}}$

Where P is the wheel load and E is the modulus of elasticity of steel, which may be taken as 30,000,000lbs. per sq. in. Substituting maximum stress in the rail multiplied by its section modulus for M. and 1·125 times the section modulus for P, we get

$$f \times 7{\cdot}9 = 1{\cdot}125 \times 7{\cdot}9 \sqrt[4]{\frac{30{,}000{,}000 \times 20{\cdot}35}{64 \times 900}}$$

or $f = 1{\cdot}125 \times \sqrt[4]{10600}$

$= 11{\cdot}42$ tons per sq. in.

From another equation, in para. 5 in Appendix I, we get

$$x_1 = \frac{\pi}{4} \times \sqrt[4]{\frac{4E.I.}{u}}$$

$= {\cdot}79 \times 41$

$\simeq 32''$ approximately.

In order to allow for the effect of the other wheel-loads on the amount of bending moment under the first driver of a " Mikado " type locomotive, with about 17 tons axle-loads on the drivers and 10 tons axle-load on the pilot wheel, which is the average ratio of axle-loads on Eastern Bengal Railway locomotives of similar types, we get, according to para. 6 in Appendix I.

Effect of 1st driver	... ...	+ 1·00
of pilot wheel ($\frac{x}{x_1} = 3{\cdot}25$) $\times \frac{10}{17}$	...	− 0·05
of 2nd driver ($\frac{x}{x_1} = 2{\cdot}06$)	...	− 0·21
of 3rd ,, ($\frac{x}{x_1} = 4{\cdot}1$)	...	− 0·04
		+ 0·70

Multiplying by this factor the maximum stress due to a single static load, we get for the maximum static stress under the first driver—

$$f_d = f \times \cdot 70 = 11{\cdot}42 \times \cdot 70 = 7{\cdot}99 \text{ tons per sq. in.}$$

9. This must now be multiplied by the necessary factor to get the stress at a speed of 60 miles per hour, which is the usual limit for unrestricted speed. From Table 8 in Appendix I, taking the results of tests with a "Mikado" type locomotive over 85lbs. rails in 1916, we get an increase in stress of ·44 per cent. for each mile per hour increase of speed greater than 5 miles per hour, *vide* para. 49—"Effect of Speed"—in Appendix I. The average for all four drivers works out to ·41 per cent. The runs were all made with the counterweight in its lowest position, as it passed over the instrument. The results of the 1915 tests were not so reliable, owing to the instruments not being as accurate as they were made later.

At 60 miles per hour the percentage increase of stress will be $55 \times \cdot 44 = 24$ per cent., and the corresponding maximum stress in the rail will be

$$f_{ds} = 7{\cdot}99 \times 1{\cdot}24 = 9{\cdot}91 \text{ tons per sq. in.}$$

10. No allowance has been made for "lateral bending," "condition of track" and "variability" factors, *vide* para. 55 in Appendix I, as the factor of safety, which has been used to arrive at the working stress of 10 tons per sq. in., may be relied on to cover these unforeseen excesses. This factor of safety has been taken as low as one-fourth, the minimum permissible breaking stress of rail steel being 40 tons per sq. in., according to the British Standard Specification.

It may appear to be very strange that treating the permanent way, as a rigid structure in one case and as an elastic one in the other, should both give practically identical results, but this is capable of explanation. The rigid structure supposition increases the impact effect very greatly, although the effective span of the rail is comparatively small. The elastic quality in the other case reduces the effect of impact because part of the approaching load gradually affects a length of rail between two consecutive sleepers, while the load is some distance away, but at the same time the sinking of the sleepers results in a proportionately greater bending moment in the rail for the same wheel-load, due to the length of effective span of the rail-girder being increased. This goes to prove that the same section of rail is suitable for the same axle-load both on girders and on ballast, the only difference being that there is more "jar" when the load is moving over a girder.

11. In order to make a further check of a better type of track than worn 75lbs. rails, the case of new 90lbs. F.F.B.S.S. rails, with a moment of inertia of 34·50 and a section modulus of 12·30, may

be considered. This type of track is sure to be stiffer than the worn 75lbs. rails and "u" in this case may be taken as 1,000lbs. per inch.

$$\text{As before,}\quad M_0 = P\sqrt[4]{\frac{30{,}000{,}000 \times 34\cdot5}{64 \times 1000}}$$

$$= 11\cdot27\ P.$$

The maximum permissible wheel load at unrestricted speed for this rail is 1·125 times its section modulus, *vide* para. 5 above. Therefore we get

$$f \times 12\cdot3 = 11\cdot27 \times 12\cdot3 \times 1\cdot125$$

$$\text{or } f = 12\cdot68 \text{ tons per sq. in.}$$

$$\text{Again as before,}\quad x_1 = \frac{\pi}{4}\sqrt[4]{\frac{4 \times 30{,}000{,}000 \times 34\cdot5}{1{,}000}}$$

$$= 36'' \text{ approximately.}$$

To obtain the static effect of wheel load of 1st driver of a locomotive, with about $27\frac{1}{2}$ tons driver axle-loads and $16\frac{1}{4}$ tons pilot-wheel axle load—

Effect of first driver		+ 1·00
,, ,, pilot wheel	$\left(\frac{x}{x_1} = 2\cdot88\right) \times \frac{16\cdot25}{27\cdot5}$	− 0·09
,, 2nd driver	$\left(\frac{x}{x} = 1\cdot84\right)$	0·20
,, 3rd driver	$\left(\frac{x}{x_1} = 3\cdot66\right)$	0·07
		+ 0·64

$$\text{Therefore } f_d = 12\cdot68 \times 0\cdot64$$

$$= 8\cdot11 \text{ tons per sq. in.}$$

Allowing for a maximum speed of 60 miles per hour we get

$$f_d = 8\cdot11 \times 1\cdot24$$

$$= 10\cdot06 \text{ tons per sq. in.}$$

which is just over the permissible limit of 10 tons per sq. inch. In actual practice a new 90lbs. rail would not be laid unless the maximum axle loads were very much less than used in these calculations so as to allow ample margin for wear of the rails.

12. Again taking the case of the modern Standard M. G. track of 60lbs. F. F. B. S. S. rails, with a moment of inertia of 14·80 and a section modulus of 6·74, we get for such track a permissible maximum axle-load of about 15 tons on the drivers and a corresponding axle-load of $8\frac{3}{4}$ tons on the pilot-wheel may be taken. In this case the modulus of elasticity of rail-support, "u," may be taken as 800lbs. per inch.

Working on these data as before, we get

$$M_0 = P\sqrt[4]{\frac{30{,}000 \times 14\cdot8}{64 \times 800}}$$

$$= 9\cdot65P..$$

$$f \times 6\cdot74 = 9\cdot65 \times 6\cdot74 \times 1\cdot125$$

$$f = 10\cdot86 \text{ tons per sq. in.}$$

$$x_1 = \frac{\pi}{4}\sqrt[4]{\frac{4 \times 30{,}000{,}000 \times 14\cdot8}{800}}$$

$$= 30'' \text{ approximately.}$$

ffect of 1st driver		$+\ 1\cdot00$
,, ,, 3rd driver	$\left(\frac{x}{x_1} = 3\cdot17\right) \times \frac{\text{[illegible]}}{15\cdot0}$	$-\ 0\cdot05$
,, ,, pilot wheel	$\left(\frac{x}{x_1} = 2\cdot20\right)$	$-\ 0\cdot20$
,, ,, 2nd driver	$\left(\frac{x}{x_1} = 4\cdot40\right)$	$-\ 0\cdot02$
		$+\ 0\cdot73$

$$f_d = 10\cdot85 \times 0\cdot73$$
$$= 7\cdot93 \text{ tons per sq. in.}$$

At 60 m.p.h. we get

$$f_{ds} = 7\cdot93 \times 1\cdot24$$
$$= 9\cdot83 \text{ tons per sq. in.}$$

In actual practice the maximum axle load on a section laid with new 60 lbs. rails, would be much less than that used in these calculations and would allow some margin for wear of the rails.

13. The results of the investigations, set forth in this note, appear to indicate that the limiting strength of a rail, for unrestricted speed, may be fixed for all practical purposes on the basis of a maximum permissible driving-wheel axle-load in tons equal to 2·25 times the section modulus of the rail. For restricted speeds, the permissible loads would be higher and could be obtained by working backwards, taking the value of f_{ds} at 10 tons per sq. in. and allowing for the restricted speed on the basis of ·44% increase in stress for each mile per hour increase of speed greater than 5 miles per hour, *vide* para. 9 of this chapter.

14. Another important point, that may also be considered, is the limiting strength of rails as compared with loads on axles, other than driving-wheel axles. The former exert no pressure on the rail due to action of counterweights and, therefore, it follows that such axles may carry heavier loads than driving-wheel axles

for the same strength of rail. This is an important consideration because, although it is possible and generally the practice to use lighter engines on unimportant and branch lines, so as to enable lighter permanent way to be laid thereon, it is not desirable to restrict the use of wagons, designed to carry loads which are economical and which should not be unduly restricted, so as to suit the lighter permanent way of the unimportant and branch lines.

15. Reverting to the analysis of the effect of driving-wheels, in paras 1 to 5 of this chapter, and omitting from the formula, at the end of para 1, the factor for effect of counterweights, we get, for the maximum load which a rail has to carry—

$$W = \frac{A}{2} \times 2.33$$

Substituting this value of W in the equation $M = \frac{Wl}{8}$, vide para 5, we get—

$$10 \times X = \frac{A}{2} \times 2.33 \times \frac{26.66}{8}$$

$$\text{or } A = X \times \frac{10 \times 2 \times 8}{2.33 \times 26.66} = 2.57\ X \text{ approximately.}$$

This represents an increase of about 11% on the permissible driving wheel axle-load.

The minimum section modulus of rail for an ordinary axle-load of A tons is, therefore, 18″ A for unrestricted speed. This would apply to coaching vehicles but in the case of goods stock, as goods trains are not likely to run at more than about 30 miles an hour, a further increase for restricted speed is permissible, which gives the following result—

$$A = \frac{1.24}{1.11} \times 2.57\ X = 2.87\ X$$

which represents an increase of about 28% on the permissible driving wheel axle-load.

As a rough rule, it may be considered that permissible maximum axle loads of goods stock may be 25% heavier than the permissible maximum axle loads of engine driving-wheels for the same rails.

III. RATE AND PERMISSIBLE LIMIT OF WEAR.

Having arrived at a definite conclusion regarding the strength of rails and the maximum axle-loads, under which they may be used for unrestricted speed, the next point to be considered is the probable life of a rail in the track, which is dependent on the permissible limit and rate of wear under the known or anticipated volume of traffic and maximum axle-load, which it will have to carry.

2. To arrive at the probable life of a rail in the main line, the first step will be to fix the permissible limit of wear, after which the weight of metal per yard, that is available for wear, can be determined. The next step will be to estimate the probable average rate of wear, in fractions of a lb. per year, from the known or anticipated volume of traffic on the railway, in which the rail is to be laid. As will be shown in the next para, three limits of wear have to be considered. The first limit, based on the strength of worn rails, will be fixed by the conclusions arrived at in the previous chapter. In order to be able to ascertain readily, when required, the permissible limit of wear for any particular axle load, it will be desirable to prepare and keep on record charts, similar to that appended as Plate I, for all standard sections of rail in use on a railway. Such curves can be easily drawn after plotting the calculated section modulus for the rail, worn down by various amounts within the specified limits.

3. The three factors to be considered, in connection with the permissible limit of wear, are (1) the limit based on the strength of the worn rails, as compared with the maximum axle-load in use, (2) that based on the reduction of depth of the head of the rail to a point, beyond which there would be a risk of wheel flanges striking the heads and nuts of the fishbolts and (3) that based on the head being worn down to a cross section, which does not provide an adequately strong table for the wheels to bear on, without risk of the inner edge of the head being bent or sheared off. In every case that limit, which is first reached as the rails wear, must be taken as the permissible limit. In most cases of rails in the main line the permissible limit would be that based on strength and the other two limits would probably apply only in the case of rails in sidings over which locomotives do not run at high speeds. The latter limits must not, however, be lost sight of as they may be effective in cases where a much heavier rail, than is warranted by the axle-loads in use, has been laid in the track.

4. The limit, based on the possibility of wheel-flanges striking the heads and nuts of fishbolts, depends on the highest possible position of any part of such heads or nuts and on the maximum permissible projection of flanges of worn tyres below rail level. The former factor can be ascertained from a drawing of the type of rail joint to be used with the rails, and the latter is limited to $1\frac{3}{4}''$ for 5′ 6″ gauge and $1\frac{1}{4}''$ for metre gauge railways in the "Schedule of Dimensions" on Indian Railways, prescribed by the Railway Board. A margin of safety is necessary in this case and this margin has been fixed at 1/8″ by the Railway Board, who have

fixed the "minimum depth of space below rail level for wheel-flange," in all points and crossings, at $1\frac{1}{2}''$ for $5'\ 6''$ gauge and $1\frac{3}{8}''$ for metre gauge railways. Drawings, similar to those reproduced in Plate II, will enable the area, of cross-section of the rails, available for wear to be ascertained in each case and from this area the weight available for wear, in lbs. per yd., can easily be calculated. With ref. to the closing sentence of para. 3 of this chapter it will be evident from Plate II that, if 60 lbs. F. F., B. S. S. rails are used with comparatively light axle-loads, their life is almost certain to be determined by the "depth" limit of wear.

5. The third limit, based on adequate cross-section of the head, is easily ascertained in the case of bullheaded rails, which may be worn down until the cross-sections of the head and foot are equal in area. The amount available for wear can be obtained from the "Table of Dimensions, showing Areas of Head, Web and Flange," embodied as Plate 2 in the "British Standard Specification and Sections of Bull Head Railway Rails." In the case of flatfooted rails the fixing of such a limit is a more difficult matter, because a greater percentage of the metal has to be concentrated in the foot of the rail, in order to get a base wide and strong enough to prevent overturning of the rail under trains. The limit, in the case of these rails, may, however, be taken at 15% of their total weight, when new, as this is about the average limit in the case of bull-headed rails. In the worst cases this limit of wear would leave nearly 30% of the original weight in the head of the worn rail, *vide* Plate 2 of the "British Standard Specification and Sections of Flat Bottom Railway Rails." In this connection attention is drawn to the fact that the limit of wear, on the basis of the preceding para., is only 9% in the case of 60 lbs. F. F. rails used in M. G. track. This is due to the fact that the size of nut used with the fishbolts is the same as for 90 lbs. rails, although the bolts themselves are $1/8''$ thinner. If the size of the nuts were reduced in proportion, the limit of wear could be increased considerably. To get full value out of a rail it should be possible to wear it down by 15% of its weight, when new. A reduction in the size of the nuts is, therefore, very necessary, if 60 lbs. F. F. rails are to be used to their full economic limit. There appears to be no reason why smaller nuts should not be used.

6. Before closing this chapter the question of rate of wear must be considered. According to Wellington the average life of good steel rails has been determined with a considerable approach to certainty, but his statement is based on the general consideration that 10 to 15 lbs. of a rail, weighing 60 to 80 lbs. per yard, is available for wear. His figure, of 150 to 200 million gross tons carried, is not based on any permissible limit of wear for any given

axle-load and cannot be used as a reliable measure for the life of all sections of rails and various axle-loads. His figure for rate of wear is, however, fairly definite and has been adopted in the investigations made by the writer. This figure is a rate of wear of 1 lb. per yard for every 10 million gross tons carried. This rate of wear will have to be checked and will probably need to be modified by each railway to suit local conditions. The rate will vary considerably in exceptional cases, such as hill sections of a railway with steep gradients, and will evidently not apply to wear on any but the easiest of curves. Rates of wear, in all cases, should be worked out from information available regarding the wear of the rails in the past on the particular section of line under consideration.

IV. SELECTION OF MOST ECONOMICAL SECTION.

1. In order to select the most economical section of rail for use in renewals or new works, it is necessary to know the probable life in the main line and also the estimated cost, laid in the track, of the rails and fastenings. The cost of sleepers should not be included, as these usually become unserviceable quicker than and have to be renewed quite independently of the rails. Another factor of importance is the condition of the rails, and consequently their return value, at the end of their probable life in the main line. Rails, that are used for about 60 years in the main line and are quite unserviceable for further use as rails at the end of that period, will have less return value in a relaying estimate than rails that have been in use for only 20 years and are still fit for use in unimportant branch lines or sidings.

2. When the probable life, initial cost and probable return value of any section of rail, which it is proposed to use, are known, a measure of its cost, suitable for comparison with other sections of rail, can be obtained by ascertaining the annuity required to redeem, in the form of a sinking fund maturing at the end of its probable life, the difference between its initial cost and return value, taking compound interest at the current rate of interest, payable on Capital borrowed for railway works. Tables of such annuities, for different periods and rates of interest, will be found in both Wellington and Trautwine. To this annuity must be added, in the case of the more expensive sections, the interest per annum on the additional original cost over and above the original cost of the cheapest section.

The simplest method of arriving at a definite result is to estimate first the probable life and return value of each of the sections of rail, from which a choice has to be made. The annual

cost, based on probable life and return value of each of those sections, should then be ascertained and by a comparison of the annual costs the most economical section will immediately become evident.

3. The choice of sections should ordinarily be limited to the standard sections in use on the Railway concerned, as the use of a large variety of sections on the same railway is not desirable and involves keeping much larger stocks of points, crossings and fittings of all descriptions. For instance, if a 5′ 6″ gauge railway had adopted as standard practice the use of rails of 90 lbs. and 75 lbs. per yard, the choice of the weight of rail to be used, for renewals on the main line or for a new branch line, would be limited to those two standard sections. Accordingly, the probable life of both the sections of rail would first be estimated and also their probable return value at the end of their life. These data, in addition to the known initial costs of the rails, laid in the track, would enable the annual cost, made up of the necessary sinking fund, referred to in para 2 of this chapter, plus interest on additional cost in the case of the 90 lbs. rails, to be ascertained for each section of rail. A comparison of the annual costs would indicate which of the two sections it would be more economical to use for the proposed work.

4. To make all clear, a specific instance may be taken and a suitable case to consider will be the selection of the more economical section of rail for renewals on a railway, which has locomotives with present and future maximum axle-loads of 17 tons and whose standard rail-sections are F.F., B.S.S. rails of 90 lbs. and 75 lbs. per yard. The average volume of traffic for four of the important B. G. Railways in India is 2·5 million gross ton-miles per running track mile per annum and this may be taken as the volume of traffic, which the rails will have to carry. According to para 6 of the previous chapter, the rate of wear of the rail will be ·25 lbs. per yard per annum. A 75 lbs. F.F. B.S.S. rail, worn down to 65 lbs., has a section modulus of just about 7·5., the minimum for 17 ton axle-loads at unrestricted speeds, but, as the "depth" limit of wear of a 75 lbs. rail is about 8·5 lbs. per yard, the probable life of the 75 lbs. rails will be 8·5 ÷ 0·25 = 34 years. Similarly a 90 lbs. rail must be worn down to about 72 lbs. yard before its section modulus is reduced to about 7·5 but, according to para 5 of the preceding Chapter, the 90 lbs. rail must not be worn down by more than 15%, i.e. 13·5 lbs. per yard, and this would give a probable life of 13·5 ÷ 0·25 = 54 years.

5. The worn 75 and 90 lbs. rails, having been worn down to one of the maximum permissible limits, will be quite unserviceable for further use as rails and their return value as scrap may be taken as 50% of their original cost. This figure has been taken because unserviceable rails appear to be readily saleable at such a rate to

the public for building and other purposes. Considering the original cost of one mile of track of each section, including cost of relaying, etc., but excluding cost of sleepers, the results obtained are tabulated below. The cost of relaying has been taken as Rs. 3,000 per mile in each case and includes carriage and other charges.

Section of rail in lbs. per yard.	Life in years.	Original cost of material per mile in rupees.	Depreciation during life in main line in rupees.	Cost of relaying in rupees.	Total loss to be recovered (col 4 and 5)	Annuity to redeem total loss @ 6% int.	Int at 6% on extra first cost	Total annual cost.
1	2	3	4	5	6	7	8	9
90	54	25,000	12,500	3,000	15,500	33	240	273
75	34	21,000	10,500	3,000	13,500	127	..	127

It will be seen from the above statement that 75 lbs. rails would be more economical in the case under consideration.

6. A suitable tabulated form, in which to compile a comparative statement of the costs of various sections of rail, from which a selection has to be made for a proposed work, is attached vide Plate III. If such a statement formed one of the enclosures, accompanying every estimate for permanent way, either new or for renewals, in the main line, it would be of great assistance to the sanctioning authority in arriving at a decision.

V. CONCLUDING REMARKS.

1. The writer's attention has been drawn to the short article, on "Ministry of Transport Regulations and the Strength of Rails," in the "Railway Gazette" of June 29th, 1923, in which article the "apparent" strength of steel and "scrap" depth of a rail are introduced into the calculation of the strength of a rail. The former might probably be safely included, if all the factors, that are referred to in para. 10 of Chapter II of this paper, could also be included in the calculation. In view, however, of the fact that lateral bending of the rail results in stresses at the outer edge of the foot of the rail greatly in excess of the average stress at the foot, it is not safe to take into consideration "apparent" strength, based on tests conducted with beams, which were presumably not subjected at the same time to lateral bending or distortion. Para 53 in Appendix I may be referred to in this connection.

2. As regards the "scrap" depth of a rail, which is referred to by the writer of the Article in the "Railway Gazette" and which is taken as the depth at which wear of the head has reduced its sectional area to that of the foot, this rule may apply to bull-headed rails but cannot fairly be applied to flat-footed rails. If it is applied to the latter, the permissible limit of wear will be so curtailed in many cases that the rails will not be economical to use. For instance, the application of this rule would limit the permissible wear in 90 lbs. F.F. rails to about 7 lbs. per yard, the same as the limit for 50 lbs. F.F. rails. On the other hand a 90 lbs. B.H. rail may, according to the same rule, be worn down to the extent of about 13 lbs. per yard. This question has already been dealt with in para 5 of Chapter III.

3. The writer has also heard mention of another rough rule that limits the wear of a rail in the main line to 10 per cent of its weight, when new. He has not been able to trace any technical paper on the subject nor can he admit that such a rule is capable of universal application without leading to anomalies, just as the "scrap" depth rule does. An inspection of the sections of 95 lbs. and 100 lbs. B.H.B.S.S. rails will disclose the fact that the whole of the extra 5 lbs. per yard, in the case of the latter section, has been used in increasing the depth of the head and there is no reason, therefore, why the 100 lbs. rail should not be allowed to wear down, during its life in the main line, by 5 lbs. per yard more than the 95 lbs. rail. Moreover, in Paper No. 2172, "On the Wear of Steel Rails," published in Volume LXXXIV of the Minutes of Proceedings of the Institution of Civil Engineers, it is mentioned that "On the London and North-Western Railway in 1877 iron rails, taken out of the line in relaying, were credited to the district at 74 lbs. per lineal yard, an average loss of 10 lbs. on the original weight. At the present time (1886) 84 lbs. steel rails are credited at 66 lbs. The stronger and purer metal retains its form and the rail generally remains uniform on the head from end to end, until it is considered too light for a safe and easy running road." It is evident, therefore, that in 1886 it was found possible to leave steel rails in the track till they had lost as much as 21 per cent. of their original weight

4. There is, however, a good deal to be said in favour of limiting the wear in the main line so as to leave a margin for further wear, when the rails are removed from the main line and laid in sidings. This procedure would enable sidings to be laid and renewed almost entirely with old rails released from the main line, so that all the money expended in the purchase of new rails would be employed in keeping the main line up to a high standard of excellence. If this principle is adopted, the maximum permissible limit of wear, based on paras 4 and 5 of the preceding Chapter,

would have to be divided up into two parts and only the first part, amounting to two-thirds of weight per yard, available for wear, would be considered in arriving at the probable life of a rail in the main line, the return value in every case being taken as that of second hand rails fit for use in sidings, etc. The adoption of this principle would affect the comparison of 90 lbs. and 75 lbs. rails, made in para 5 of the preceding Chapter, and, taking the return value of second hand rails as two-thirds of the original cost, a revised result would be obtained as follows:—

90 lbs. rails -probable life 36 years- Annual Cost Rs. 330
75 lbs. rails—probable life 22 years—Annual Cost Rs. 230

So that the 75 lbs. rails would still be more economical to use in the case under consideration.

The adoption of this principle would necessitate a modification in the sample form of comparative statement of the costs of various sections of rail, Plate III. After the columns of "Permissible Wear in lbs. per yard" another column, "Permissible Wear in Main line," would have to be added.

5. Since the bulk of this paper was written, the writer has made further investigations of existing conditions on Indian Railways to check the general conclusion arrived at. On the South Indian Railway, some years ago, the running of locomotives with 15 ton axle-loads over 60 lbs. F.F. rails was sanctioned with a speed restriction of 25 miles per hour. A correction for restricted speed, as indicated in para 13 of Chapter II, gives 13 ton axle loads at unrestricted speed as equivalent to 15 tons at 25 miles per hour. The section modulus, of one of the worst worn rails now in the track, is about 5.8 and 2¼ times this figure gives the 13 ton axle load, referred to above.

Again it is known that old 41¼ lb. F.F. rails have been in use for many years under 8 ton axle-loads, at restricted speed of about 25 miles per hour. This is equivalent to 7 ton axle-loads at 60 miles per hour, which is less than the permissible maximum, even when the 41¼ lb. rails are worn down to 40 lbs. per yard and their section modulus is about 3.3. Finally there is the case of the 30 lbs. F.F. rails, in use on the Gwalior Light Railway, 2′0″ gauge, with 6 ton axle-loads and a maximum speed of 15 miles per hour. A correction for speed gives an equivalent axle-load of about 5 tons at 60 miles per hour. As the section modulus of the 30 lbs. F.F. rails, when new, is about 2·38 and an axle-load of 5 tons at 60 miles per hour requires a minimum section modulus of 2·22 only, the use of 6 ton axle-loads at 15 miles per hour leaves ample margin for wear of the rails.

(Sd.), A. F. HARVEY.

PLATE III.

COMPARATIVE COSTS OF VARIOUS SECTIONS OF RAIL.

Section of rail in lbs. per yard.	Permissible wear in lbs. per yard.			Probable average volume of traffic in gross ton-miles per mile per annum	Probable life (Col. 2, 3 or 4, whichever is less, x 10,000,000 ÷ col. 5)	Estimated cost of 1 mile of rails and fastenings in Rupees.	Estimated return value at end of probable life in rupees.	Cost of relaying in rupees.	Total loss to be recovered (Col. 7 — Col. 8 + Col. 9).	Annuity to redeem total loss at 6% interest.	Interest at 6% on extra first cost.	Total annual cost.	Remarks.
	Stren-gth basis.	Depth basis.	15% basis.										
1	2	3	4	5	6	7	8	9	10	11	12	13	14

APPENDIX I.

Extracts from the Report of the Special Committee, appointed by the American Railway Engineering Association, to report on Stresses in Railroad track.

II.—THE ACTION OF TRACK AS AN ELASTIC STRUCTURE.

3. *The General Behaviour of Track under Load.*—A proper conception of the fundamentals underlying the action of track under load may be had only by considering the track as an elastic structure under load: The wheel loads are applied on the top of the rails, the rails act as flexible beams which rest on flexible supports (ties), and the ballast and roadway on which the ties rest are themselves yielding or flexible. The action of the various parts of this elastic structure affects the action of other parts. It is evident that the quality of flexibility and elasticity and stiffness of the supporting substructure constitutes an important element in track action, influences very greatly the action of the rail, and affects the stresses developed in the various parts of the track.

Due to the stiffness of the rail and the yielding of its supports, the load from a wheel will be distributed over a number of ties. It is evident that the amount of yielding of the supports affects the values of the moments and stresses developed in the rail. As the distribution of the wheel load among a number of ties produces upward pressures or tie re actions of varying amounts, the determination of these tie reactions is connected with the problem of determining analytically the stresses in the rail. The properties of elasticity and stiffness in the rail, the tie, the ballast, and the roadway enter in a complex manner into the development of the stresses in the track structure, the relative stiffness of the various parts affecting the results in any one part. The spacing of the wheels of locomotives and cars longitudinally along the track also influences the division of the load, as pressures on the various ties, and hence influences the value of the stresses developed in rails, ties and ballast. The track is flexible, and its action under load is exceedingly complex, especially under the variable conditions found in the bearings, ballast pressures, and roadway resistances.

Before attempting to give an analytical treatment of the moments and stresses developed in the parts of the track structure,

it may be well to discuss in a general way the action of that structure. It is believed that this may be helpful in forming proper conceptions and in showing that certain notions of the manner in which the rail acts are incorrect and misleading.

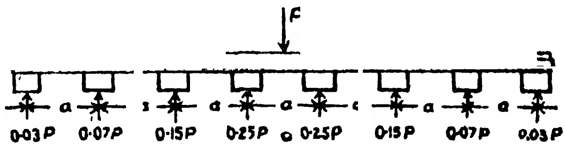


Fig. 1. Assumed tie reactions for one-axle load.

A number of writers have obtained expressions for the bending moment and stresses in a rail by considering the latter as a simple beam supported on the two adjacent ties, with the wheel load at a point half way between. This assumption gives a positive bending under the wheel of $\frac{1}{4}$ Pa, where P is the wheel load and a is the distance from centre to centre of ties. Other writers assume the beam to be fully restrained over the adjacent ties, this makes the positive moment $\frac{1}{8}$ Pa and the negative moment $\frac{1}{8}$ Pa. Among other values which have been put forward are those of 0·18 Pa for the positive bending moment under the load, and 0·09 Pa for the negative moment, which is considered to be over the adjoining tie. In all these it is virtually assumed that the load is taken only by the two ties adjacent to the load.

The conditions for a single wheel load may be approximated by taking the upward tie pressures as the loads on the rail and the wheel load as the reaction and in effect considering the rail cut at the last tie. The wheel load is distributed over a number of ties. The proportional part of the wheel load for each tie reaction depends on the tie spacing, the stiffness of the tie and of the supporting substructure (ballast and roadway), and the stiffness of the rail. Consider that the tie reactions, which approximate the values found in tests, are somewhat as given in Figure 1. For this assumed distribution of tie reactions the bending moment under the load will then be 0·63 Pa, if we consider that the rail is not held down in such a way as to give negative reactions and negative resisting moments away from the wheel. It is seen from this illustration that a single load may give a high bending moment in the rail.

If, now, we consider rail with an indefinitely large number of evenly spaced wheel loads, the tie spacing being, say, not more than one-third of the wheel spacing, it can be shown that, for a given wheel spacing there is relatively little difference in the tie reactions until the wheel spacing becomes quite large. Assuming for present purposes that the tie reactions are equal, and that the wheels are at points midway between ties (Fig. 2), the positive

bending moment under loads three tie spaces apart is found to be about $0{\cdot}263\ Pa$, and the negative bending moment $-0{\cdot}154\ Pa$, and $0{\cdot}345\ Pa$ and $-0{\cdot}156\ Pa$, respectively, when the wheel spacing is four tie spaces. Expressing the bending moments in terms of the wheel spacing, l, the values become $0{\cdot}088\ Pl$ and $-0{\cdot}051\ Pl$ for $l=3a$, and $0{\cdot}086\ Pl$ and $-0{\cdot}039\ Pl$ for l is equal to $4a$. It is readily seen from this that, for the conditions assumed, the bending moments—and therefore the stresses in the rail—will be dependent on the wheel spacing, and that this influence will continue until the wheel spacing becomes so great as to approach the conditions of single loads.

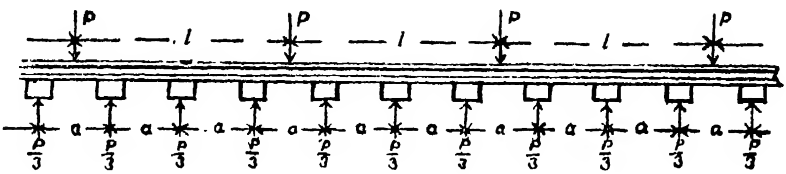


Fig. 2. Series of loads with assumption of equal tie reactions.

The foregoing refers only to an indefinitely large number of wheel loads. For a small number the results will be greatly modified. In case two, three, or four wheels are spaced as above, it may be expected that the positive moment developed under the first and last loads will be greater than the foregoing values, and the moment under intermediate wheels somewhat less than at the outer wheels. The moment of this difference will depend on the properties of the track, including the stiffness of the rail. When there are other wheel loads, as truck wheels, not too far away, their effect is to modify the moments produced under the main wheels. On the whole, the problem is very complicated.

It is apparent that, for conditions here considered, changes in the closeness of tie spacing have relatively small effects on the bending moment developed in the rail by a given wheel loading, thus, for a wheel spacing equal to three tie spaces and an indefinitely large number of wheels thus spaced, the positive moment is about $0{\cdot}088\ Pl$; and, if the ties were spaced so closely as to approach conditions of uniform distribution of bearing pressures from wheel to wheel, the positive bending moment would be approximately $0{\cdot}083\ Pl$. It is also well to note that, by this method of analysis the bending moment under the wheel may be expected to be nearly as much for wheels placed over ties as when they are midway between ties. The foregoing discussion is based on an assumption of uniform resistance of the substructure, namely, that the stiffness of the elastic support is the same at each tie. It is evident that the stresses in the rail will be modified by the varying conditions of the tie, ballast, and roadway from point to point along the track.

Another important element in the problem of determining stresses in track is the effect of speed of locomotive and train. On this matter analysis alone can give little real information, and it must be expected that reliance must be placed on experimental data.

The reaction of the tie or its upward pressure on the rail depends on the stiffness of the yieldability of the ballast and roadway, and also on the stiffness of the rail, which, of course, is dependent on its moment of inertia. For good track and for a wheel spacing of not more than three or four tie spaces, the tie reactions for the ties between wheels will not vary greatly from each other. In front of the front wheel and behind the rear wheel of a set of wheels, and also in front of and behind a single wheel, the division of the reactions among various ties will be dependent on the stiffness of the track (rail, tie, ballast and roadway). The determination of this stiffness is one of the problems connected with the experimental work.

The distribution of the upward pressure of ballast against a tie along its length may be expected to vary with the tamping and with the ballast and roadway conditions, and also depends on the dimensions of the tie. For usual conditions of good track, it would seem that the upward pressure will continue from the rail to the end of the tie and for at least a similar distance inside the rail. The exact distribution will depend on the amount of bending of the tie and on the permanent depression made in the ballast by the previous applications of load, as well as on the yieldability of the ballast and roadway. It will help in getting a conception of the action of the tie and ballast to consider the tie to be set on a bed of stiff springs, under load, the tie bends and the springs compress in proportion to the load put on them. The stiffness of the springs depends on the nature of the tie bearing and the consolidation of the ballast and other bearing material, and their elastic properties. At the middle point of the tie the springs will generally have little bearing resistance. Figure 3 gives a general notion of the distribution of the load along a tie. However, it must be expected that changes in the conditions of ballast and roadway—like freezing and thawing—differences in bearing conditions of adjacent ties, and the differences in resistance to repetition of pressure on the ballast along the length of the tie, greatly modify the distribution, and such changes may be expected to increase the bending stresses in the tie. It is usual to think of the distribution of pressure across the width of the tie as being nearly uniform; that is, to consider the whole width of the tie as equally effective in transmitting pressure from the tie to the ballast. The ballast, however, is composed

of non-cohesive particles. As the transmission of pressure in directions other than the vertical is dependent on friction between particles, the vertical pressures at the edge of the tie must be less than the pressures transmitted from the middle of its width, and this difference results in a distribution of pressure far from uniform across the width of the tie. For ties which are spaced not too far apart, there is something of a reaction from the adjoining tie, which may be expected to improve the distribution across the face. On the whole, however, the upward pressure against the tie cannot be uniform across its width.

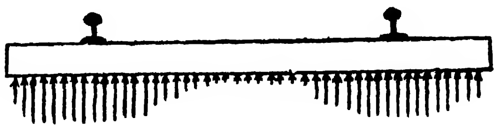


Fig. 3. A distribution of pressures along a tie.

The ballast, as a part of the structure of the track, in addition to other important purposes, such as drainage, serves to transmit the tie pressures and reactions to the roadway, and acts to distribute the pressure more nearly evenly over the surface of the roadway. The laws governing the distribution and transmission of pressure through the ballast must be expected to have an important bearing on the proportioning of the track structure. The formulation of these laws and the determination of constants relating to stiffness or yieldability must wait experimental work.

The roadway itself, acting as a support, also serves to transmit pressures and to distribute them to the surface of the earth below. The conditions of the roadway and the materials of which it is made may be expected to affect the action of the track. Little is known about this..

Enough has been stated to show that the problem of the stresses in track is not a simple one, that it involves a large number of elements which have the nature of variables, that these variables enter into the problem in a complex manner, and that it is necessary to have a diversity of experimental data relating to the several variables before attempting to formulate the laws governing the stresses in track.

4. *Analysis of Track Action.*—An analytical treatment of the action of track under load has a value in the comparison of experimental data. It will be of use in establishing the physical properties of track and should be an aid in forming proper conceptions of the manner in which track acts under load. It will be found to be a convenience in discussing the effect of rail section, tie spacing, driver and wheel spacing, depth of ballast and its stiffness, and condition of roadway. Such analyses are based on

the theory of flexure, and involve complicated mathematical procedure. It may not be expected that an analysis of track action will fit acurately the many variables of track and, besides, the track varies in its properties from point to point. What is wanted is an analysis that may readily be used and that may easily be applied to combinations of wheel loads, to variations in wheel spacing and to particular physical conditions of track. Most analytical treatments give results in such complicated form that their application is time-consuming. The simplified forms of analysis may not have a wide range of applicability. Various methods of analysis have been examined, including those given in foreign publications. Much time and considerable effort have been devoted to a study of possible analyses, and a variety of methods of attack have been taken up. As a result, it is concluded that the method of analysis which is based on the assumption of a continuous elastic support under the rail is by far the most convenient, most easily applied, and most comprehensive in its application to the questions involved in the work of the Committee. This analysis lends itself very readily to a discussion of the general problems of track.

The assumption of a continuous support in place of tie supports is not an element of serious inaccuracy for the close tie spacing and large rail sections used on American rail roads, especially as the use of values of track stiffness determined from data taken from tests on ordinary track carries into the constants established much of the condition of concentrated tie loads. The results of this analysis are similar in general character to those tried using concentrated tie loads. The method has been found to be more general and to have fewer limitations than the methods based on concentrated tie loads.

The term, modulus of elasticity of rail-support, is introduced as a measure of the vertical stiffness of the rail-support. It may be defined as the pressure per unit of length of each rail required to depress the track one unit. It represents the stiffness and yieldability of tie, ballast, and roadway, but does not involve the stiffness of the rail. As applied to ordinary track, the load on one rail required to depress one tie one unit, divided by tie spacing, will give the modulus of elasticity of rail-support. As an illustration, consider that a series of wheel loads which depress the track an average of 0·3 in. gives a load equivalent to 10,000 lb. per tie for each rail, and that the tie spacing is 22 in., the modulus of elasticity of rail-support is then 1,500 lb. per inch of length of rail per inch of depression. The value of the modulus of elasticity of rail-support is so related to tie-spacing and tie dimensions, depth of ballast, quality of tie, solidity of roadway,

character of tamping and surface, and other conditions of the track and its maintenance, that it will vary considerably according to the quality of the track.

The method of analysis will be developed, first for a single wheel load and then for a combination of wheel loads.

5. *Depressions, Upward Pressures, and Bending Moments in Rail for Track having a Continuous Elastic Support; Single Wheel Load.*—Assume that the rail is supported continuously on an elastic support and that the support has a constant modulus of stiffness, that is, that the depression of the track and the resulting upward pressures on the rail are directly proportional to each other.

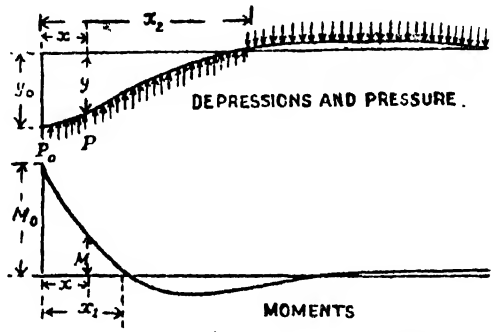


Fig 1. Distribution of Depression, and Bending Moment for Single-wheel Load:

Assume, further, that the track construction is such that negative pressures may be developed. The following nomenclature will be used (see Figure 1):

P = wheel load on rail at point which will be used as the origin of abscissas,

E = modulus of elasticity of steel,

I = moment of inertia of section of the rail,

Y = depression of rail at any point, x, it being assumed that there is no play or back-lash in the track, downward displacement of rail is negative, however, in the applications to track, the ordinary downward depressions of track will be spoken of as positive,

y_0 = depression of rail at point of wheel load ($x=0$),

p = upward pressure against rail per unit of length of rail at any given point,

p_0 = upward pressure against rail per unit of length of rail at the given wheel load ($x=0$),

u = an elastic constant which denotes the pressure per unit of length of each rail necessary to depress the track (rail, tie, ballast, and roadway) one unit, for the system of units ordinarily used, it will be expressed in pounds per inch of length of rail required to depress the track 1 in.

u represents the stiffness of the track, and involves conditions of tie, ballast and roadway, it is termed the modulus of elasticity of rail-support,

M = bending moment in rail at any point;

M_0 = bending moment in rail at point of wheel load due to single wheel load ($x = 0$),

x_1 = distance from wheel load to point of zero bending moment in rail,

x_2 = distance from wheel load to point of zero upward pressure, it will be shown that x_2 is $3 x_1$,

e = base of natural system of logarithms 2·7183.

The fundamental condition on which the analysis is based is that the track depression at any point and the upward pressure on the rail per unit of length at the same point are directly proportional to each other. In other words, $p = uy$.

It will be recalled that, in the mechanics of beams, the derivatives of the elastic curve (first, second, third and fourth), in their order, represent or are proportional to (1) the slope of the elastic curve, (2) the bending moment in the beam, (3) the shear, and (4) the intensity of the load. In the case in hand, the fourth derivative (the intensity of the load) has the unique relation of being directly proportional to the original function, given by the equation of the elastic curve or curve of depression of track.

From the fundamental condition, the differential equation of equilibrium is:—

$$E.\,I.\,\frac{d^4 y}{dx^4} = u\,y \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

This differential equation is satisfied by the following equation:

$$y = -\frac{P}{\sqrt[4]{64\,E\,I\,u^3}}\,e^{-x\sqrt[4]{\frac{u}{4\,E.I.}}}\left(\text{Cos.}\,x\sqrt[4]{\frac{u}{4\,E.I.}} + \text{Sin.}\,x\sqrt[4]{\frac{u}{4\,E.I.}}\right) \qquad . \quad . \quad . \quad . \quad . \quad (2)$$

The successive derivatives of this expression are:

$$\frac{dy}{dx} = \frac{2P}{\sqrt{16\,E\,I\,u}}\,e^{-x\sqrt[4]{\frac{u}{4\,E.I.}}}\,\text{Sin.}\,x\sqrt[4]{\frac{u}{4\,E.I.}} \qquad . \quad . \quad (3)$$

$$M = E\,I\,\frac{d^2 y}{dx^2} = P\sqrt[4]{\frac{E\,I}{64\,u}}\,e^{-x\sqrt[4]{\frac{u}{4\,E.I.}}}\left(\text{Cos.}\,x\sqrt[4]{\frac{u}{4\,E\,I.}} - \text{Sin.}\,x\sqrt[4]{\frac{u}{4\,E.I.}}\right) \qquad . \quad . \quad . \quad . \quad . \quad (4)$$

$$E\,I\,\frac{d^3 y}{dx^3} = -\frac{P}{2}\,e^{-x\sqrt[4]{\frac{u}{4\,E.I.}}}\left(\text{Cos.}\,x\sqrt[4]{\frac{u}{4\,E.I.}}\right) \qquad . \quad (5)$$

The equation for intensity of pressure against the rail is

$$p = -u\,y = P\sqrt[4]{\frac{u}{64\,E.I.}}\;e^{-x\sqrt[4]{\frac{u}{4\,E.I.}}}\left(\text{Cos.}\,x\sqrt[4]{\frac{u}{4\,E.I.}} + \text{Sin.}\,x\sqrt[4]{\frac{u}{4\,E.I.}}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The mathematical derivation of these equations will not be given, but the solution is seen to be correct, because at the same time, two types of conditions are satisfied:

1.—The differential equation is satisfied by Equation (2) for all positive values of x.

2. All necessary conditions at special points are satisfied as follows:

$$E\,I\frac{d^3y}{dx^3} = \frac{P}{2} \text{ for } x = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

$$\frac{dy}{dx} = 0 \text{ for } x = 0 \text{ and } x = \infty \quad . \quad . \quad . \quad . \quad . \quad (b)$$

$$y = 0 \text{ for } x = \infty \quad . \quad . \quad . \quad . \quad (c)$$

The following special value of the functions will be useful:

The distance from the wheel load to the point of zero bending moment in the rail (M = O in Equation (4)) is

$$\frac{\pi}{4}\sqrt[4]{\frac{4\,E.I.}{u}} \quad (7)$$

The value of the maximum bending moment in the rail (which is at the wheel load) (x = O in Equation (4)) is

$$M_0 = P\sqrt[4]{\frac{E.I.}{64\,u}} = 0\cdot318\,P\,x_1 \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The value of the maximum track depression (which is at the wheel load) (x = O in Equation (2)) is

$$y_0 = -\frac{P}{\sqrt[4]{64\,E.I.\,u^3}} \quad . \quad (9)$$

The value of the maximum intensity of upward pressure (which is at the wheel load) (x = O in Equation (6)) is

$$P_0 = P\sqrt[4]{\frac{u}{64\,E.I.}} = -u\,y \quad . \quad (10)$$

The distance from the wheel load to the point of zero upward pressure on the rail ($p = 0$ in Equation (6)) is

$$x_2 = \frac{3\pi}{4} \sqrt[4]{\frac{4\,E.I.}{u}} = 3x_1 \qquad . \quad (11)$$

Figure 5 gives master diagrams for (1) the moment developed in the rail, and (2) the intensity of pressure against the rail and the depression of the rail, as determined from the foregoing equations. The diagrams represent relative values. The bending moment under the wheel load is given as unity, and the values of the bending moment at other points (given as ordinates of the bending moment curve) are expressed in terms of the bending moment at the wheel load. The intensity of upward pressure (represented by the ordinate to the pressure curve) is also expressed in terms of the intensity of pressure at the wheel load as unity. Similarly, the abscissas of the two diagrams (bending moments and pressures) are expressed in terms of the distance from the wheel load to the point of zero bending moment as unity; *i. e.*, as abscissa ratios. For any given track conditions, the value of the maximum bending moment, M_0, may be computed by Equation (8) and the distance x_1 to the point of zero bending moment by Equation (7). To get the bending moment at any given point, find the ratio of x for the given point to x_1 and take the ordinate from the diagram by using this ratio as the abscissa. The bending moment in the rail at the given point will then be found by multiplying the value of the maximum moment, M_0 (already computed), by the ordinate found from the diagram. Similarly, the value of the intensity of pressure at a given point may be determined by multiplying the intensity of pressure under the wheel load by the ordinate for pressure at a given point obtained from the diagram.

As an illustration, consider a 100 lb. rail section (I = 44) and that, for the track conditions, u = 1500 lb. per inch of length of rail per inch of depression x_1 is found to be 34 in. For a point 66 in. from the wheel load, the abscissa ratio is then $\frac{x}{x_1} = \frac{66}{34}$ = 1·94. From the master diagram (Figure 5), the bending moment ratio at the abscissa ratio, 1·94, is—0·20; that is, the

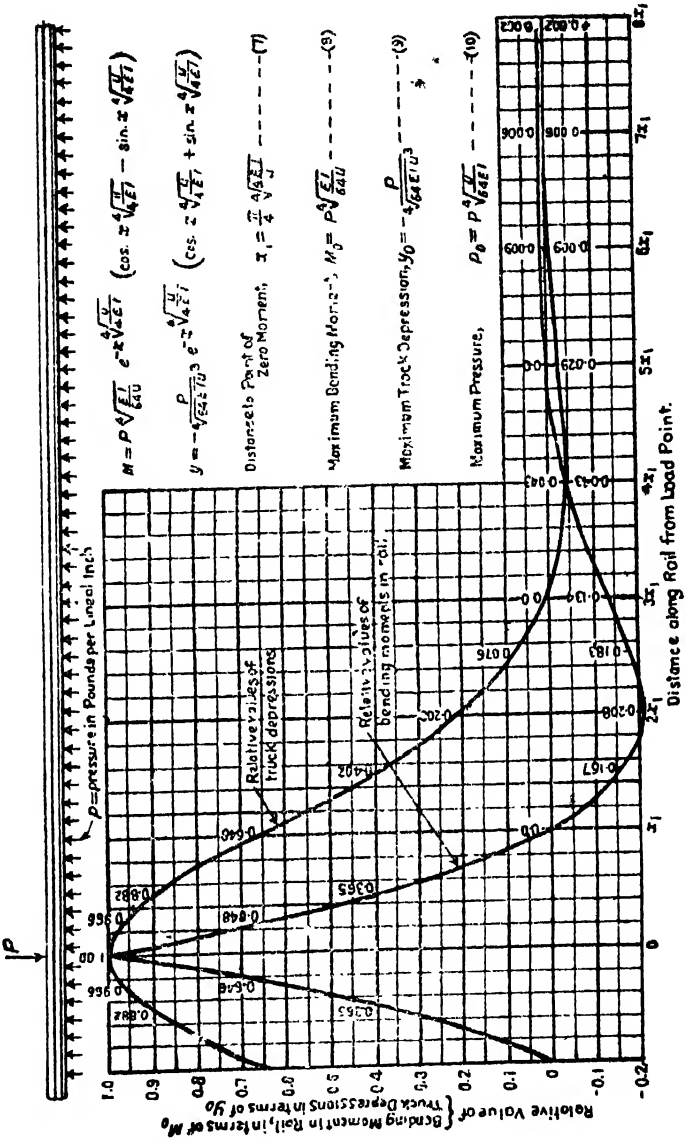


Fig. 5. Master diagram for (1) moment developed in the rail, and (2) intensity of pressure against the rail, and depression of the rail, single-wheel load.

bending moment of 66 in. from the wheel load is 0·20 of that of the wheel load, and is negative. By Equation (8) the maximum moment M_0 is 10·8 P. The bending moment at a point 66 in. from the wheel load is then the product of M_0 and 0·20, which is—0·216 P. For the same point (x=66 inch), the relative value of the intensity of pressure at the wheel load, p_0 is 0·0115 P. The pressure 66 in. away is then the product of p_0 by 0·22, which is 0·0025 P.

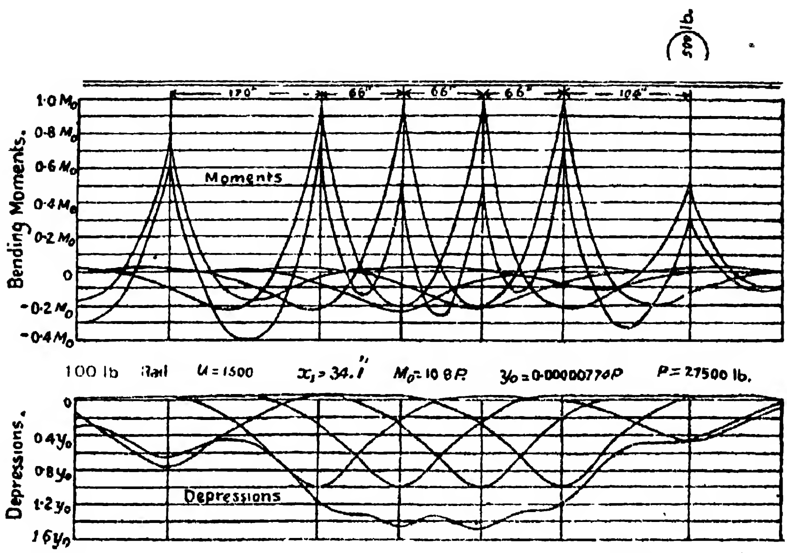
It may be well to call attention to the effect of changes in the various properties of track on the resulting track depressions and bending moments, in rail, as indicated by the several equations already given for a single wheel load. From Equation (9) it is seen that y_0 the track depression under the wheel, varies directly as the magnitude of the wheel load, P, and that it varies inversely as the fourth root of the moment of inertia of the rail section and inversely as the three-fourths power of the modulus of elasticity of rail-support. By this formula, doubling the moment of inertia of the rail section will result in a track depression under the wheel 84 per cent. as great as that for the lighter rail. Increasing the stiffness of the track support in such way as to double the modulus of elasticity of rail support will result in a track depression 59 per cent. as great as that of less stiff track. From Equation (8) it is seen that M_0 the bending moment in the rail under the wheel, varies directly as the magnitude of the wheel load, p, and that it varies directly as the fourth root of the moment of inertia of the rail section and inversely as the fourth root of the modulus of elasticity of rail-support. By this formula, doubling the moment of inertia of the rail section will result in a bending moment in the rail under the wheel 1·19 times as great as that of the lighter rail. Increasing the stiffness of the track support in such way as to double the modulus of elasticity of rail-support will result in a bending moment in the rail under the wheel 84 per cent. as great as that for the less stiff track. It should be noted that the foregoing applies to results for a single wheel load on a rail, the effect of two or more wheel loads is discussed in the following article.

6. *Combination of wheel loads.*- To find the effect of a combination of wheel loads on the track depressions and the pressures and the bending moment in the rail, as may occur with a given type of locomotive, the equations and diagrams for a single wheel load may be applied by the use of the principle of superposition, *i. e.*, by considering that, at a given point along the rail, the combined effect of two or more wheel loads is the algebraic sum of the effects of the individual wheel loads. The effect which each wheel produces at any given point may be determined from the master diagrams (Figure 5), and the cumulative effect of the several loads may then be found by adding the components produced by each wheel load. This method of superposition of components is applicable to bending moments as well as to track depressions and pressures. The method may best be described by an illustrative example.

Take a Mikado locomotive, with the wheel loads and wheel spacings given in Figure 6, and let the problem be to calculate the bending moments in the rail at various points. In using Figure 5,

take as the abscissa the ratio, $\frac{x}{x_1}$, where x is the distance from the given point to the wheel load the effect of which is to be determined and x_1 is the distance from the wheel to the point of zero bending moment in the case of a single wheel load. The bending moments will be obtained in terms of the maximum bending moment for a single wheel load (Equation (8)).

Fig. 6. Bending Moments and Track Depressions for Mikado Locomotive from Analysis, 100 lbs rail.



To find the bending moment produced by a wheel load at a section in the rail x distant from the wheel load, take from the moment diagram in Figure 5 the ordinate (which gives relative values of bending moments) corresponding to the given abscissa ratio, $\frac{x}{x_1}$. The values may best be kept as relative values and considered as effects of the several wheel loads until the components have been summed. The bending moment at the given point may then be found by multiplying the maximum bending moment for a single wheel load (as found from Equation (8)) by the ratio found by the summation of components. Where the wheel loads are unequal, use the ratio of the wheel loads in the calculations, thus, if the effect of the pilot truck wheel on a point at the first driver is to be found, use the ratio $\frac{12,500}{27,500}$.

Consider that the track conditions are such that the modulus of elasticity of rail-support, u, is 1,500 lb. per inch of length of rail per inch of depression. Consider a 100 lb. rail section, with I=44.

The value of the bending moment under a wheel load, where uninfluenced by other wheel loads, becomes, for the constants of the track, from Equation (8), $M_0 = 10\cdot8$ P. From Equation (7), $x_1 = 34$ inch. For the distance from the first driver to the pilot track wheel the abscissa ratio, $\frac{x}{x_1}$ is $\frac{104}{34} = 3\cdot06$. For the distance from the first driver to the 2nd driver the abscissa ratio, $\frac{x}{x_1}$ is $\frac{66}{34} = 1\cdot94$. For the distance from the fourth driver to the trailer the abscissa ratio, $\frac{x}{x_1}$ is $\frac{120}{34} = 3\cdot53$. Take ordinates from the Figure 5 for the several abscissa ratios. The effects of the several wheels are then found, and these components are added algebraically.

Bending Moment at First Driver :-

Effect of first driver	+ 1·00
Effect of pilot truck wheel $\left(\frac{x}{x_1} = 3\cdot06\right) - 0\cdot13 \times \frac{12500}{27500}$	- 0·06
Effect of second driver $\left(\frac{x}{x_1} = 1\cdot94\right)$	- 0·20
Effect of third driver $\left(\frac{x}{x_1} = 3\cdot88\right)$	- 0·05
	+ 0·69

The bending moment at the first driver is then 0·69 of that due to the weight of the first driver if it acted alone. The bending moment at this point becomes $M = 0\cdot69\ M_0 = 7\cdot45$ P = 205,000 lb.-inch.

Bending moment at Second driver :—

Effect of second driver	+ 1·00
Effect of first driver $\left(\frac{x}{x_1} = 1\cdot94\right)$ ...	− 0·20
Effect of third driver $\left(\frac{x}{x_1} = 1\cdot94\right)$ ...	− 0·20
Effect of fourth driver $\left(\frac{x}{x_1} = 3\cdot88\right)$ ...	- 0·05
Effect of pilot truck wheel $\left(\frac{x}{x_1} = 5\cdot0\right) - 0\cdot0 \times \frac{12500}{27500}$ ...	− 0·00
	+ 0·55

The bending moment at the second driver is then 0·55 of that due to the weight of the second driver if it acted alone. The moment at this point becomes $M = 0\cdot55\ M_0 = 5\cdot94$ P = 163,000 lb.-inch.

Bending Moment at Trailer :—

Effect of trailer load	+ 1·00
Effect of fourth driver $\left(\frac{x}{x_1} = 3\cdot53\right) - 0\cdot08 \times \frac{27500}{20000}$ ...	0·11
Effect of first tender wheel $\left(\frac{x}{x_1} = 4\cdot0\right) - 0\cdot04 \times \frac{20000}{20000}$	0·04
	+ 0·85

The bending moment at the trailer is then 0·85 of that due to the trailer load if it acted alone, and the bending moment is 0·85 $M_0 = 9{\cdot}18$ P = 184,000 lb.-inch.

The method may be applied in a similar way to the determination of the bending moments at points away from wheel loads. The values of the negative bending moment may thus be found. Figure 6 shows in a general way the distribution of bending moments for the conditions assumed in the preceding illustration and for the locomotive shown. The light lines show the moment produced by the individual loads, the heavy line is the resultant moment due to the combination of wheel loads.

If the weights on the several drivers differ, as in the case with the Mikado locomotive of the Illinois Central Railroad used in the tests, the difference in the wheel loads may easily be taken into account in the calculations.

The track depressions caused by the assumed locomotive loading may be calculated by a similar process.

At any point along the rail the components of track depressions caused by the individual wheel loads are found, and their algebraic sum gives the track depression resulting from the combination of loads. The values may be taken from Figure 5 (which gives track depressions in terms of y_0, the depression under single wheel load) for any given value of $\frac{x}{x_1}$ where x is the distance from the given point on the rail to the wheel load the effect of which on the track depression is to be determined and x_1 is the distance from the wheel to the point of zero bending moment, in the case of a single wheel load. The values of the ratios thus found for the effect of the several loads may then be added algebraically, the product of this resultant ratio and y_0 is the resultant track depression due to the combination of loads. Figure 6 illustrates the track depression for the Mikado locomotive used in the example illustrating the method of calculating bending moments. The light lines show the track depression produced by the individual wheel loads, the heavy line is the resultant track of depression due to the combination of wheel loads. To illustrate the method of calculation, consider the case of track depression under the first driver, as follows:—

Effect of first driver	... .	+ 1·00
Effect of pilot truck wheel	$\left(\frac{x}{x_1} = 3{\cdot}06\right) \times 0{\cdot}01\frac{12500}{27500}$	= 0·00
Effect of second driver	$\left(\frac{x}{x_1} = 1{\cdot}94\right)$	+ 0·23
Effect of third driver	$\left(\frac{x}{x_1} = 3{\cdot}88\right)$	− 0·04
		+ 1·19

The track depression at the first driver is then 1·19 times that due to the weight of the first driver if it acted alone. Since y_0, the depression under the first driver acting alone (from Equation (9)) would be 0·00000771 P = 0·213 in. for the conditions already assumed for the track, the track depression at this point will be 1·19 y_0 = 0·254 in. The heavy line in Figure 6 gives the resulting track depressions at all points along the locomotive. The vertical pressures may be found from the track depressions by the use of the modulus of elasticity of rail-support, u.

Figures 7 and 8 give values of bending moment in rail and track depressions for an Atlantic locomotive having the wheel loads and wheel spacing shown, the former for the worn 85-lb. rail section used on the test track, and the latter for the 125-lb, rail section, the value of u being 1500 lb. per in. per in.

Figure 9 gives values of bending moment in rail and track depression for a single car having the loads shown, and Figure 10 gives values for the truck wheels of two adjacent cars, the rail being the worn 85-lb. section of the test track on the Illinois Central Railroad and the value of u being 1500 lb. per in. per in.

It is seen that, by the method here described, the effect of a combination or two or more wheel loads on the track depression and the bending moment in rail may be determined for the condition of continuous support here assumed. It is evident that a second wheel

Fig. 7. Bending Moments and Track Depressions for Atlantic Locomotive from Analysis, 85 lbs. rail.

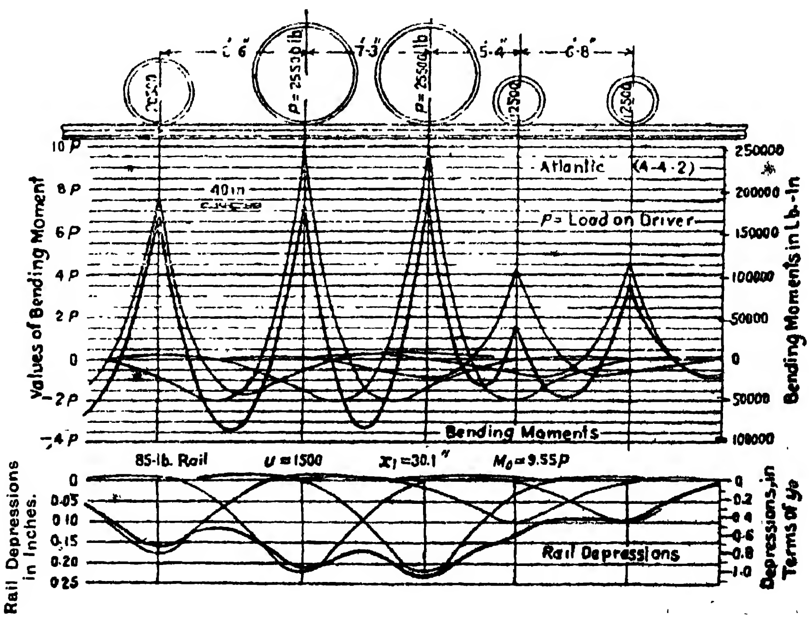
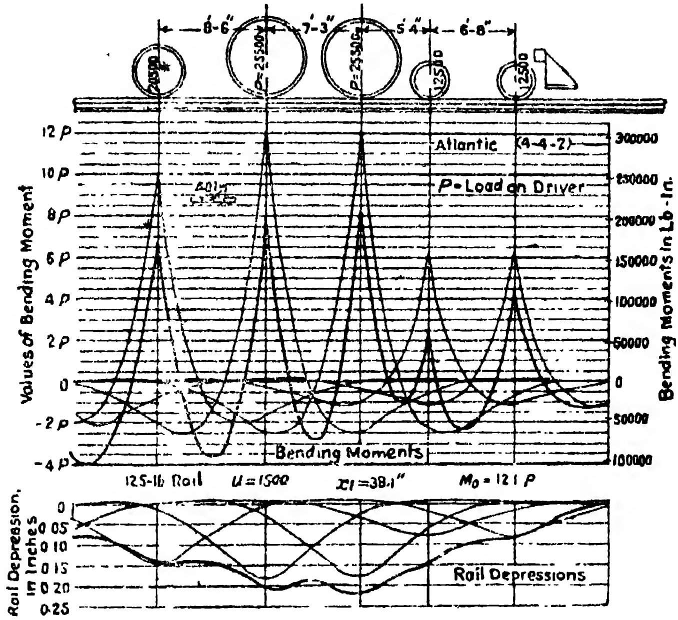


Fig. 8. Bending Moments and Track Depressions for Atlantic Locomotive from Analysis, 125 lbs. rail.



load placed within a limited distance from another wheel will cause a smaller bending moment to be produced in the rail at the wheel, and likewise a larger track depression than would be produced with a single wheel load. The distance between wheels for which there will be a reduction in bending moment at the first wheel will depend on the rail section used and on the modulus of elasticity of rail support. A third wheel within this limiting distance (usually on the other side of the first wheel) will also act to decrease still further the bending moment in the rail at the first wheel. The effect

Fig. 9. Bending Moments and Track Depressions for loaded car, from Analysis, 85 lbs. rail.

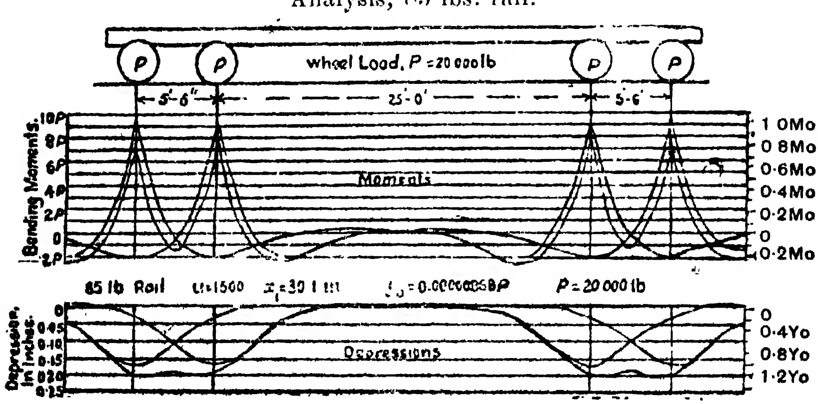
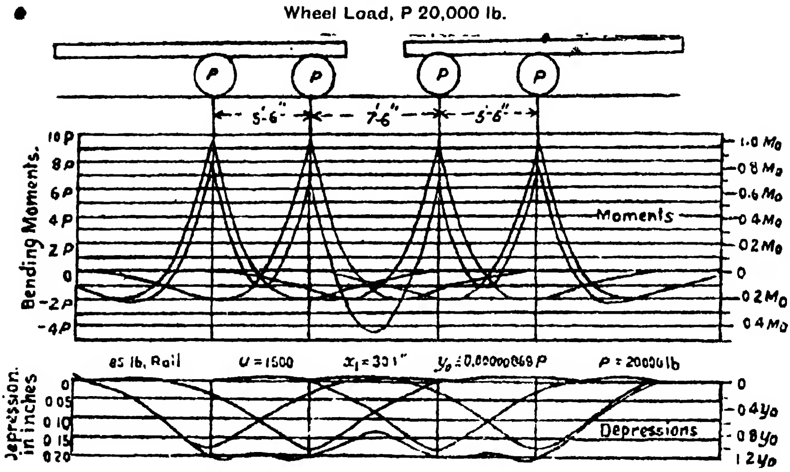


Fig. 10. Bending Moments and Track Depressions for trucks of two adjacent cars, from Analysis, 85 lbs. rail.



of changes in the values of the moment of inertia of the rail section and of the modulus of elasticity of rail-support on the magnitude of the bending moments and track depressions will depend on the spacing of the wheels. For any given wheel loading and spacing, this effect may be readily determined.

7. *Discussion of Applicability of Analysis.* From the foregoing illustrations it is seen that the method of applying the analysis is not complicated. It is readily applied to determining the effect of a combination of wheel loads having any arrangement and any spacing, and takes into account the effect of the rail section used and the stiffness of the track. Although the cross-ties constitute a discontinuous support, their width forms a considerable part of the rail length, and, as the distance from a single wheel load to the point where the track depression is zero covers from four to six tie spacings, in such track as that on which the tests were made, the assumption of continuous support may not be expected to be generally much in error for the usual conditions of good track, especially as the method used for determining the value of the modulus of elasticity of rail-support will carry into this value some of the conditions attending the discontinuous support. Naturally, the magnitude of the modulus of elasticity of rail-support will depend on the size and spacing of the ties, the quality and depth of the ballast, the stiffness of the roadway, and the general condition of the track, and this property of track is one which must be determined by tests at different locations and under a considerable range of conditions.

It may appear at first thought that the assumption involved in the analysis that the rail-support is capable of developing negative pressures—may interfere with the accuracy of the results. Since there is play between the rail and the spikes, and since the ties cannot be expected to pull down on the rail, at least until there is some upward movement of the rail, there will be a region ahead of or behind a single wheel where little negative pressure may be developed in the track. However, in a combination of wheel loads, with the spacing usually found in locomotives, the effect of adjacent wheel loads in the analysis is such that there will be no negative pressure except ahead of the pilot truck wheel, and here the weight of the rail itself will assist in developing the negative pressure. In the case of cars, the analysis may give negative pressures at a point between the front and rear trucks of a car, but not between that of one car and the next. It may be expected that the absence of resistance to the upward movement of the rail, as shown by a rail lifting from the tie, will tend to increase the bending moment in the rail at the first wheel over that given if the negative pressure were developed.

Perhaps a more serious element affecting the accuracy of this analysis, and of any analysis which could readily be applied to combinations of wheel loads, lies in the fact that at small loads the magnitude of the track depression may be greater accordingly than at large loads, in other words, that the modulus of elasticity of rail-support is not a constant—a condition which may exist when the track is in a poorly tamped condition. However, for the heavier wheel loads, like the drivers and trailer, this influence may not be very important. For a condition where the modulus of elasticity of rail-support is not a constant, the principle of superposition, which is utilised in most methods of analysis involving flexure of structure, is not applicable, and hence any treatment based on the actual relation between pressure and depression will be altogether too complicated for any practical use.

It may not be expected that any method of analysis will give results that will fit accurately with experimental values. The variables of track are numerous and uncertain. Notwithstanding this, a usable analytical treatment is of great value in the comparison of experimental data and in acquiring a conception of the fundamentals of track action. It is believed that the analysis here given is acceptable from most points of view. Possibly in the future it may be found practicable to make empirical modifications of it which will fit more closely the data of tests.

* * * *

IV.—RESULTS OF TESTS.

35. *Form of Presentation.*—In reporting the results of the tests, the effort has been made to present only those matters which seem to have a bearing on the fundamentals of track action and the problems of track, and to give the essential results, free as far as possible from the mass of details of the test data. When it is stated that the tests have involved the making, reading, recording, and reducing of more than 250,000 observations on rail strains alone, the need for presenting only the essentials will be apparent. Generally speaking, only averages of a considerable number of values are presented. Some use of individual results will be made in the discussion on the variation of individual values from the average value. It has been thought best to present the results largely in graphical form. This method allows general comparison to be made readily. Tabular values are also given for some of the principal results.

The results presented in this report relate principally to stresses in rail and to the depression of track as a whole. The action of the tie, the transmission of pressure through ballast and roadway, and other related matters must be reserved for a later report.

Data relating to depression of track under one-axle load, two-axle load, and locomotive loading under static conditions will first be presented, then data on stresses in rail for these loadings and for moving load tests with locomotives, and, following these a general discussion of the effect of speed, influence of rail section, effect of wheel spacing, condition of track, etc.

36. *Depression of Track under load.*—Flexibility, elasticity, and stiffness are important properties of railroad track. The quality of the track is affected by variations in these properties. It is apparent even to a casual observer that the track depresses under wheel loads. The weight from the wheel load is distributed by the rail among adjacent ties, and vertical pressures are set up in ties, ballast and roadway. The pressures transmitted by rail, tie, ballast, and roadway compress or otherwise deform these various parts of the track structure, the vertical deformation and movement of the different parts together forming the total track depression. Generally speaking, the action has the nature of elastic deformation, and, when the wheel load is removed, the track resumes its normal position, wholly or partly, according to the condition of the track and the nature and weight of the load. The stiffness and flexibility of track are dependent on the section of the rail and its flexural properties, the dimensions and spacing of the ties, and the nature, quality, and condition of the ballast and roadway.

At this place no effort will be made to analyse the parts played by the rails, ties, ballast, and roadway in making up the track depression. The total depression will be reported—the combined effect of rail, tie, ballast and roadway. At another time a discussion will be made of the relation between the deformations of the several parts of the track structure. The following general statement is given as an estimate of the division of the depressions in the various parts, in what may be called good track, under the drivers of a Mikado locomotive: compression of the tie under the rail and effect of bending of tie to bring it to full bearing on the ballast along its length, 0·05 in., compression of 24 in. of stone ballast immediately under the rail, 0·15 in., compression of roadway immediately under rail, 0·15 in. The bending of the rail between the ties is slight, the deflection of the rail between two adjacent ties under the weight of the driver of a Mikado locomotive on 85-lb. rail amounting to not more than 0·01 in. in a tie spacing of 22 in. For heavier rails, the deflection, of course will be less.

Whether the magnitude of the track depression is directly proportional to the load applied, or varies considerably from direct proportionality, is dependent on the nature of the track and its condition. For the best track in well-tamped condition (freshly surfaced), the tests indicate that the relation between the load and the resulting depression approaches direct proportionality, that is the depression of the track is directly proportional to the load applied. For mediocre track and track which is not well kept up, it is evident from the results of the tests that the first part of the load applied produces a greater depression than a later equal additional increment of load. The effect of this on stress in the track is important.

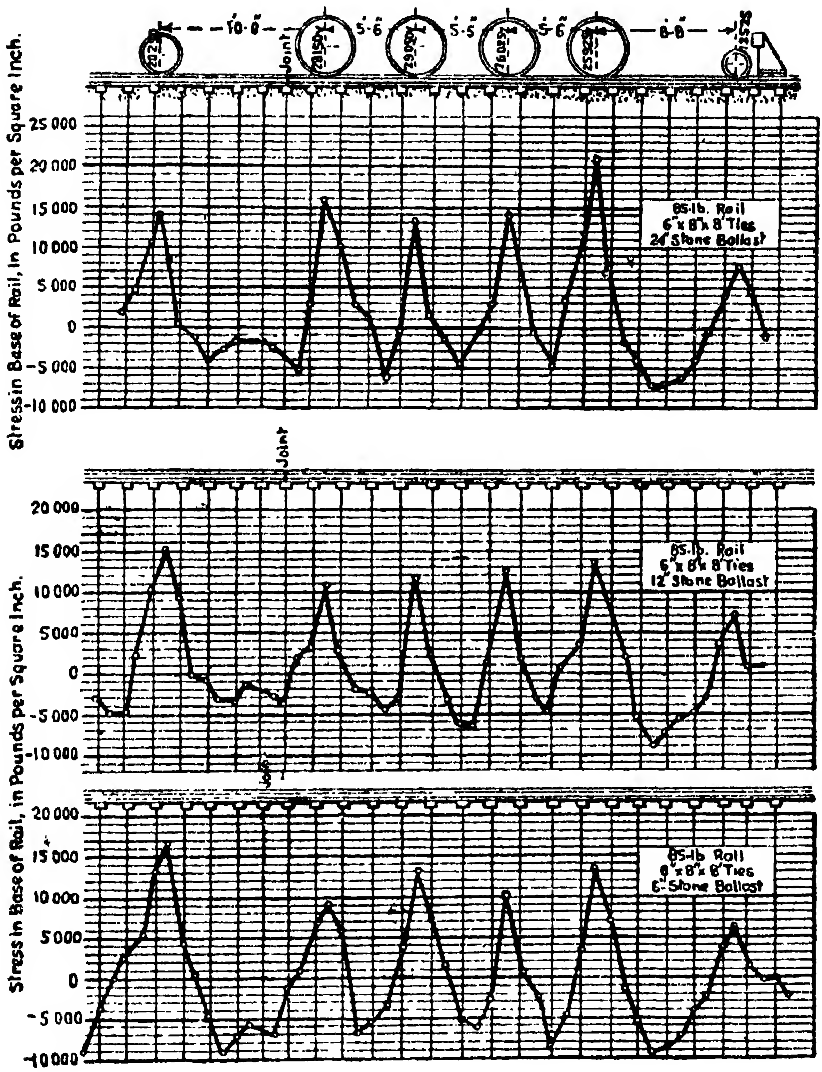
The foregoing refers to the relation between vertical pressures and the resulting vertical deformations or depressions at any point along the line of the rail, both at and away from the wheel load. Away from the load, the pressure of the rail on the tie will vary from tie to tie, and therefore the consequent depression will vary, but, at any point, the downward pressure of the rail and the upward pressure of the tie must, of course, be equal to each other. In the tests, the magnitude of the track depression along the rail has been measured and the distribution of vertical pressure among the ties may be estimated from the data obtained. Records of results will be given of track depression for one-axle load, two-axle load, and locomotive loading.

* * * * * *

43. *Stresses in Rail: Static Load Tests with Mikado Locomotive.*—In Figs. 66 and 67 are given stress-distribution profiles for static load tests with the Mikado locomotive on rail of 85 lb. and 100 lb. section on the test sections of track on the Illinois Central Railroad. For the 85-lb. section, tests were made on three depths of ballast and two sizes of ties: for the 100lb. section tests were made on one depth of ballast. In all these tests the track was in a freshly tamped condition.

The stress-distribution diagrams give a very good indication of the variation in stresses along the rail with respect to the position of the wheel loads. The maximum stresses in the rail are directly under the wheels, positive moment being developed at these points. Negative moments occur at points between the wheels. The stress under the inner two drivers is generally less than that under the outer drivers and that under the front driver is generally somewhat greater than that under the rear driver. In the upper diagram of Fig. 67, the stress under the front driver is quite low. The values plotted on this diagram are the average of two sets at the same spot, the locomotive used in the second not being the one used in the first test. The results of the two sets are concordant. Another peculiarity of this diagram is that the stresses under the inner drivers are higher than would be expected. It will be seen that the highest negative moment in all these tests is between the front truck wheel and the front driver. The stress here ranges from 40 to 60 per cent. of that developed under the front driver. The stress under the trailer is nearly as much as that under the outer drivers, although the load on the trailer is only about three-quarters as much as that on a driver. Comparing these stress-distribution diagrams with Fig. 6, which was obtained from the analysis of track action, it is seen that the general form of the curves and the way in which the stresses vary with respect to the position of the wheel loads are quite similar.

Fig. 66. Stress Distribution Diagrams.
Static load tests on Illinois Central Railroad with Mikado Locomotive.



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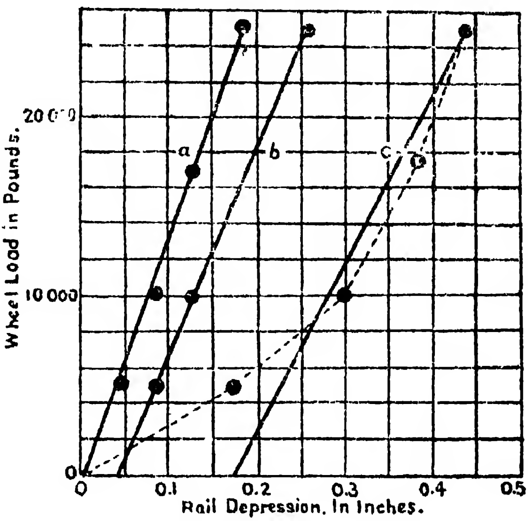
47. *Modulus of Elasticity of Railway-support.*—The term "modulus of elasticity of rail-support" has already been defined as the pressure per unit of length of each rail required to depress the track one unit. It measures the vertical stiffness of the support of the rail. The magnitude of the modulus of elasticity of rail-support is dependent on a number of elements, such as the

compressibility of the tie and its flexure stiffness, the breadth and length of the tie, the tie spacing, the character of the bearing of the tie on the ballast, the thickness, solidification, and stiffness of the ballast, the nature of the roadway, and the way in which the pressures are distributed over it. As the stresses developed in the rail and the division of load among tie reactions are affected directly by the magnitude of the modulus of elasticity of rail-support, this modulus may serve as one criterion of the quality of track. It will be of interest, therefore, to learn what range of values of the modulus of elasticity of rail-support may be expected for various kinds and conditions of track.

The definition of the term implies that the modulus of elasticity of rail-support is a constant for any given condition of track, that the track has the usual property of an elastic body. In the discussion of the data on track depression, it was shown that the depression of track may not be proportional to the load applied, under such conditions, the modulus of elasticity of rail-support would not be a constant. The tests indicate conditions of track which may be classified in three groups: The plotted depressions may give a straight line passing through the origin, as at *a*, Figure 106, denoting a constant modulus of elasticity—a condition which may be expected in well-tamped track, and where the tie has a full bearing immediately below the rail and for some distance each way along its length, even when only a small load is applied. The plotted depression may form a straight line which passes to the right of the origin, as at *b*, denoting that some condition exists such as the presence of some play between tie and ballast immediately below the rail necessitating the bending of the tie before a full and fair bearing is obtained along its length, in this case the depression may be found by the use of a constant modulus of elasticity of rail-support plus a constant. At *c*, the condition is similar, except that the points do not give a straight line relation, in this case the relation of depression to load may be approximated by a constant modulus of elasticity of rail-support drawn to pass the points somewhat as shown in the figure. For track in poor condition, the relation of depression to load may be expected to vary from the straight line relation even more than shown in the figure. As conditions of track vary greatly, the relation between track depression and load may be expected to cover a considerable range of values and conditions. It is evident that the constant modulus of elasticity of rail-support applies very well to the conditions of best track, and that, for poor and indifferent track, the actual relation between depression and load departs considerably from a straight line relation.

Values of the modulus of elasticity of rail support have been calculated from the data of the track depressions by adding the depressions at the several ties for the length of the depressed track or for the length for which the loads used are considered to affect the track depressions. The total load on the wheels within the

Fig. 106. Typical load depression Diagrams.



length used was then divided by the number of ties in this length, and by the tie spacing, in inches. The values of the modulus of elasticity of rail support are thus given in pounds per inch of length of rail per inch of depression. The symbol, *u*, is used to represent it. A continuous load of *u* pounds per inch

TABLE 4.- Values of Modulus of Elasticity of Rail-Support.

Depth of ballast in inches	Size of ties in inches	Condition of tamping.	85 LB. RAIL. Loco-motive	85 LB. RAIL. One Axle	85 LB. RAIL. Two Axle	100 LB RAIL. Loco-motive	100 LB RAIL. One Axle	100 LB RAIL. Two Axle	125 LB RAIL. Loco-motive	125 LB RAIL. One Axle
24	6 by 8	Before	.	1 170	1 180	. . .	.	1 090	.	1 640*
			. .	1 190	.	. . . .	1 080	1 100	. . .	1 820*
			. . . .	1 640		.	1 030	.	. .	1 600
			.	. . .	. . .	.	880	. . . . .	. . . . . .	. . . . . .
	Average		. . . . . .	1 330	1 180	. . .	1 000	1 090	. . . . . .	1 690
24	6 by 8	After	1 650	. . . . . .	. . . . . .	1 510	1 710	. . . .	1 540	1 920
			1 660	. . . . .	. . . . .	. . .	1 130	. . . .	1 420	1 840
			1 570	. . . . .	. . . . .	. . .	. . . . . .	. . . .	1 800	1 560
			. . . . . .	. . . . .	. . . . . .	. . . . . .	. . . . . .	. . . .	1 830	2 010
			. . . . . .	. . . . .	. . . . . .	. . . . .	. . . . . .	. . . .	1 380	. . . . . .
	Average		1 630	. . . . . .	. . . . . .	1 510	1 570	. . . .	1 590	1 380

* This track, marked as "before tamping," seemed to be in as good condition as "after tamping."

85 LB. RAIL.

Depth of ballast in inches.	Size of ties, in inches.	Before Tamping. Loco-motive.	Before Tamping. One Axle.	Before Tamping. Two Axle	After Tamping. Loco-motive.	After Tamping. One Axle.	After Tamping. Two Axle.
12	6 by 8	....	880[x]	910[x]	990	810	910
		....	910[x]	950[x]	1 040	1 000	870
		....	930[x]	....	1 000	940	....
		....	1 270[x]	....	....	....	....
		....	1 210[x]	....	....	....	....
	Average	....	1 030	930	1 010	920	890
12	7 by 9	....	1 300	800	1 230	....	880
		....	1 500	870	1 110	1 170	980
		....	1 060	950	1 150	....	....
		....	1 190	....	....	....	....
	Average	....	1 260	870	1 160	1 170	930
6	6 by 8	....	951	970	990	....	....
		....	810	880	1 100	....	....
		....	1 280	....	1 030	....	....
		....	1 030	....	1 180	....	....
		....	1 010	....	....	....	....
	Average	....	1 020	920	1 080	....	....

[x] This track, marked as "before tamping," seemed to be in as good conditions as "after tamping."

of rail on each rail would depress the track 1 inch. For the locomotive loading, in computing the modulus of elasticity of rail support the total track depression was used, the static tests with locomotive were all made on track in well-tamped condition. For the one-axle and two-axle load tests, the lines of the load-depression diagrams were studied and here some allowance was made for the play at light load for track conditions which gave indications of such play, net track depressions being used for the calculations. In some cases a general compromise straight line was used. The values reported are given tentatively, and may need empirical modifications later in order to fit into other experimental data.

Table 4 gives the values of the modulus of elasticity of rail-support as calculated from the track depression. The conditions of track are not stated very definitely but, even in track marked "before tamping" the track was in good surface, and only in a few instances was it in need of tamping. The values derived from

the tests for the different methods of loading on the same track agree very well. There seems to be some tendency toward a higher value of the modulus in the track having the heaviest rail. It is apparent that the character and condition of the track greatly influence the magnitude of the modulus of elasticity of rail-support. The value for the modulus on the track of the Illinois Central Railroad with 24-inch ballast may be taken as about 1,600 lb. per inch. This test stretch is on the north-bound track. For the track on 6-inch and 12-inch ballast, the values are approximately 1,000, except for the track on 7 by 9 inch. ties, where the values are higher, say, about 1,200. These last named stretches of test track are on the south bound track. Although the embankment for the two tracks was built at different times, it is not known that the two parts of the embankment have any special differences in condition. In all these test stretches, there is a tie spacing of 22 inches where the tests were made. For the track used for freight service, which was ballasted with 6 inches of cinders in not very compact conditions, the value of the modulus of elasticity of rail-support is about 750. For the track of Champaign and Havana Branch of the Illinois Central Railroad, with about 6 inches of fine cinder ballast above a light embankment of loam, tie spacing varying from 22 to 26 inches (56-lb. rail), the modulus of elasticity of rail-support found was about 530. At the time, the track was not in good condition at the point where the test was made. Some of the ties were partly decayed.

For the track of the Delaware, Lackawanna and Western Railroad, information on the depression of track and the condition of the track is not complete, and only an estimated value of the modulus of elasticity of rail-support can be given. This track was evidently stiffer than that of the Illinois Central Railroad. The value, 2,200 lb. per inch, is probably representative of this track. The track had 18 inches of trap rock ballast below the tie, and the material of the roadway below was such that it was very solid. The spacing of the 7 by 9 inches by 8 feet 6 inches ties averaged about 22 inches.

* * * *

49. *Effect of speed.*—The position of the plotted points in Figures 69 to 91 indicates that a rectilinear relation between stress in rail and speed of locomotive fits the data more generally and more satisfactorily than any other form. The variations of the plotted points from the straight lines of the diagrams are generally not greater than may be expected when variations in conditions of track and locomotive, errors of instruments and observations and other accidental causes of variation are taken into account.

Generally, for any tests, the lines of a diagram are parallel, or nearly so.

Table 8 gives values of the increase in stress due to speed, as obtained from the rectilinear relation of the diagrams. In the columns marked A the increase is expressed as pound per square inch increase in stress for each mile per hour increase in speed greater than 5 miles per hour. In the columns marked B, the effect of speed is given as a percentage of the stress in the rail at 5 miles per hour for each mile per hour increase of speed greater than 5 miles per hour. It will be seen that the values for the increase for positive moment range from about 0·3 to 1·2 per cent. increase for each mile per hour increase in speed. Values higher than 0·9 per cent. are found in a number of cases.

The increase found in the tests on the Delaware, Lackawanna and Western Railroad, given in table 9, are of the same character, but the values are somewhat smaller than those found in the tests on the Illinois Central Railroad.

It will be noted that the effect of speed for the different rail sections given in the tables shows considerable variation. The cause of these variations is not known. It may be due partly to the track, partly to the locomotives, and partly to accidental conditions of the runs at the tests. Although the runs were all made with the counterweight in its lowest position as it passed the middle instrument, some of the tests were made with the three instruments on the rail at the right side of the locomotive and some with the three instruments at the left side, hence, in one case the counterweights on the other side of the locomotive opposite the three instruments were ahead, and in the other case behind, the position of the middle instrument. A study of the tests shows no variations traceable to these deferences of conditions.

The heavier rail section appears to give a somewhat higher proportional increase of stress with increase of speed than the lighter. The indications in the tests on track of the Illinois Central Railroad are that the Mikado locomotive gives a rate of increase somewhat greater than the Atlantic and the Pacific. The tender trucks give a still higher rate of increase, though, of course, the amount of the stress is less than that under the drivers.

The proportional increase in the stress for negative moment is large and rather irregular, as would be expected from the smaller value of this stress and greater variations of conditions to which it is subjected. The sum of the stresses for positive and negative moment shows greater uniformity in the tests than does either set of stresses.

TABLE 8.—Increase in Stress in Rail Due to Speed Tests on Illinois Central Railroad.

MIKADO (2-8-2)

Weight of Rail, in Pounds per Yard	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
85	1915	132	0.83	63	0.98	120	0.82	56	1.73	96	0.77	53	1.30	120	1.10	53	1.60	107	0.74	60	1.78	81	0.95
85	1916	108	0.64	24	0.45	78	0.44	39	0.95	29	0.18	21	0.42	81	0.59	41	1.30	72	0.44	39	0.77	80	0.73
100	1915	75	0.63	21	0.51	93	0.78	48	1.90	84	0.88	45	1.50	77	0.77	38	1.50	102	0.95	38	1.20	85	1.20
125	1915	57	0.51	82	1.50	50	0.49	67	2.90	55	0.58	57	2.10	62	0.77	62	2.40	55	0.58	59	1.70	54	0.98
125	1916	85	0.78	32	0.87	70	0.65	28	0.83	90	0.92	30	1.00	78	0.94	43	1.40	115	1.20	35	1.20	95	1.50

ATLANTIC (4-4-2)

Weight of Rail, in Pounds per Yard	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
85	1915	96	0.65	30	0.59	53	0.29	32	0.76	53	0.30	40	1.40	94	2.10	63	1.30	93	1.30
85	1916	133	0.84	25	0.45	59	0.33	32	0.65	113	0.61	34	0.91	194	?	41	1.20	95	1.20
100	1915	71	0.60	40	0.93	116	0.86	5	0.11	58	0.40	9	0.22	55	1.50	40	1.80	82	1.60
125	1915	82	0.90	31	0.24	62	0.59	13	0.42	73	0.63	31	1.20	66	1.70	38	1.50	69	1.50
125	1916	124	1.20	28	0.71	82	0.72	27	0.71	75	0.63	35	1.10	95	2.10	29	0.88	80	1.30

PACIFIC (4-6-2)

Weight of Rail, in Pounds per Yard	Year	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
85	1915	66	0.43	47	0.89	58	0.40	6	0.12	60	0.43	13	0.30	66	0.30	36	1.40	53	0.08	27	0.75	28	0.35
125	1916	73	0.65	-2	0.04	62	0.61	55	0.12	57	0.62	11	0.23	86	0.84	35	0.91	118	2.30	24	0.47	100	1.60

Exceptions from uniformity of action are found in the tests. In Fig 82, the stresses under the rear driver are less at high speeds than at low speeds, and the data at the several speeds are consistent. In other instances, one driver or one truck wheel shows a much higher increase with speed than do the other wheel.

It should be remembered that the diagrams and tests give the average of a large number of runs, and, of course, the increases found for individual runs are considerably greater than the average values.

No discussion of the cause of the increased stress at the higher speeds will be made at the present time.

*   *   *   *

53. *Relation of the Stress on the Two Sides of the Rail.*—It may appear natural to think that, since the wheel load is a vertical load, the flexural action in the rail will be such that the fiber stress will be uniform all the way across the base of the rail. Even if the pressure of the wheel is not applied centrally over the head of the rail, the effects of this eccentricity of loading will be

to produce vertical flexural stresses in the rail and probably a torsional effect, little lateral horizontal bending of the rail may be expected to result from this source. In planning the tests, lateral bending of the rail was not expected to be an important element. In the earlier test work, therefore, the strain measurements with both the strain gauge and the stremmatograph were made at one edge of the base of the rail only, the outer edge being used because of its greater convenience. The stremmatograph tests showed marked irregularities and seemingly erratic results, which were unexplainable on the ordinary assumption, and steps were taken to find the source of the variations. Tests were made with the position of the stremmatograph reversed on the rail, in order to measure the deformation at the inner edge, and the results were compared with those found with the measurements at the outer edge of the rail, all other conditions as to track, position of locomotive, and speed remaining the same. The average of the stremmatograph measurements at the two edges of the base of rail was found to be fairly uniform and consistent for runs which were comparable, but the stress at one end was usually different from that at the other, sometimes more than twice as great. Generally speaking, the higher value was found at the outer edge of the rail. The instruments already made were then rebuilt in such way that each stremmatograph measured the deformation both at the inner and outer edges of the base of rail, and this improvement was followed in instruments made thereafter. It may be added that, in static tests with a locomotive, the results of measurements made with a strain gauge showed differences in stresses at the two edges which were quite similar to the results found in the moving-load tests, and that static tests made with the loading device showed little difference in stress on the two sides of the rail.

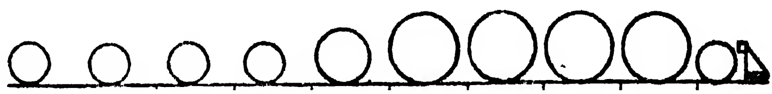
As another check on the phenomenon, measurements were made at the base of the rail, to see whether the rail showed lateral movement as the wheel moved by. It was observed that there was an outward movement at the base of the rail immediately under the wheel and an inward movement at a point between wheels, the rail thus forming along the length of the locomotive a horizontal curve something like a sinusoid. A similar outward and inward movement occurred in the other rail, and, in the observations referred to, the movements of both rails were outward under a given axle and inward at points between axles, in other words, the gauge of the base of rail was increased at the wheel points and decreased at points between wheels. This movement was small, but it was measurable, ranging from 0·01 inch to 0·03 inch, with the 85-lb. rail in the preliminary test referred to. It will be

seen, later, that the movement of the rail is not always of the character just described, there being several forms of movement.

With an outward bending of the rail at a point under a wheel load, the tensile stress at the outer edge of the base of rail is increased over that due to vertical bending, and with an inward bending at a point between wheels, the compressive stress at the outer edge of the base of rail is also increased, the stress at the inner edge of rail being described in both cases. In the head of the rail the effect on the stresses is reversed, but, as the head is narrower than the base, the difference in stresses at the two sides of the head of the rail is smaller than that found at the base.

TABLE 10.—Values of the Ratio of the Stress at One Edge of the Base of Rail to the Mean of the Stresses at the Two Edges Prepared Test Sections of Track.

85 lbs. rail. 6 in. × 8 in. 8 ft. Ties. 12 in. Stone Ballast.



n miles per hour	Instrument No.										
5	2	1·12	1·16	1·10	1·15	1·09	1·10	1·18	1·16	1·13	1·05
	3	1·13	1·07	1·05	1·11	1·05	1·00	1·02	-1·04	1·03	1·06
	4	1·03	1·01	1·03	1·11	1·04	1·09	1·08	1·08	1·00	1·01
	7	1·18	1·10	1·09	1·15	1·02	1·07	1·10	1·02	1·09	1·07
15	2	1·11	1·06	1·05	1·13	1·10	1·08	1·15	1·12	1·08	1·04
	3	1·02	-1·02	1·01	1·07	-1·01	1·02	1·07	1·01	-1·01	—1·05
	4	1·12	1·09	1·07	1·13	1·01	1·09	1·11	1·02	1·07	1·01
	7	1·07	1·07	1·04	1·17	1·05	1·10	1·11	1·02	1·07	—1·14
25	2	1·13	1·11	1·07	1·19	1·12	1·02	1·10	1·08	1·11	-1·07
	3	1·05	1·03	—1·05	1·00	—1·08	-1·04	1·10	1·08	1·01	-1·09
	4	1·12	1·10	1·10	1·13	1·07	1·02	1·07	1·09	1·03	1·08
	7	1·09	1·01	1·17	1·10	1·00	1·05	1·05	1·07	1·05	—1·07
35	2	1·01	1·05	1·00	1·00	1·01	1·06	1·04	1·05	1·18	-1·15
	3	1·03	—1·02	—1·01	1·03	1·00	—1·06	—1·05	1·02	—1·01	-1·06
	4	1·10	—1·11	1·07	1·04	1·01	—1·02	1·05	-1·01	1·00	—1·02
	7	1·05	1·04	1·09	1·05	1·07	—1·02	—1·11	—1·06	1·02	1·00

125 lbs. rail. 6 in. × 8 in. × 8 ft. Ties. 24 in Stone Ballast.

Speed, in miles per hour	Instrument No.										
5	8	1·15	1·11	1·18	1·09	1·14	1·12	1·11	1·05	1·20	1·14
	9	1·10	1·10	1·02	1·14	1·13	1·11	1·20	1·17	1·11	1·09
	11	1·07	1·09	1·05	1·15	1·11	1·14	1·26	1·23	1·13	1·13
	12	1·05	1·05	1·00	1·21	1·20	1·22	1·25	1·22	1·25	1·12
15	8	1·08	1·05	1·10	1·04	1·07	1·05	1·06	1·03	1·09	—1·01
	9	1·11	1·09	1·01	1·13	1·10	1·12	1·26	1·15	1·15	1·13
	11	1·07	1·05	1·02	1·12	1·15	1·19	1·30	1·24	1·19	1·20
	12	1·17	1·11	1·24	1·22	1·24	1·16	1·37	1·32	1·31	1·15
25	8	1·07	1·02	1·02	—1·02	1·02	1·07	—1·02	1·06	—1·03	—1·01
	9	1·13	1·12	1·04	1·18	1·10	1·09	1·26	1·25	1·19	1·13
	11	1·12	1·12	1·06	1·16	1·10	1·11	1·23	1·19	1·24	1·13
	12	1·25	1·22	1·13	1·24	1·11	1·19	1·17	1·20	1·23	1·12
35	8	—1·03	—1·06	1·06	—1·03	—1·01	1·07	—1·07	1·00	—1·10	1·03
	9	1·09	1·06	1·03	1·09	1·07	1·04	1·25	1·15	1·09	1·04
	11	1·12	1·12	1·06	1·15	1·08	1·10	1·15	1·07	1·12	1·11
	12	1·10	1·08	1·14	1·20	1·10	1·22	1·11	1·22	1·17	1·28

Table 10 gives values of the ratio of the stress at one edge of the base of rail to the mean of the stresses at the two edges. Where the minus sign is given, the stress at the inner edge is the greater, otherwise, that as the outer edge is the greater. The table is a sample of the data obtained (the complete data being very voluminous), and is probably representative of the observations. The values given are those found by individual instruments, averages of several instruments would mask the effect of variations in track and of variations in movement of locomotive. In looking over the table, it should be borne in mind that the runs were made in such a way that the counterweight of the front driver, on the side of the track on which there were three instruments, was at its lowest point as it passed the middle instrument, and that the succeeding wheels made their records at a later time and therefore, the measurement of stresses for the several wheels was not made simultaneously. Naturally, the values cover quite a range. There are many ratios as high as 1·30, and a number as great as 1·50 (which means that the stress at one edge of the base is 1·86 and three times as great,

respectively, as the stress at the other edge). The few ratios higher than 1·75 doubtless may not be fully reliable.

The ratios at points midway between wheels (not given in the table) run to even higher values, and are more discordant, as might be expected from the fact that the magnitude of the stress is less than that at points under the wheels. The difference between the numerical values of the stresses at the two edges, as may be expected, is in general less at the point between wheels than at points under the wheels.

55. *Method of Estimating Maximum Flexural Stress in Rail for Given Conditions of Track and Loading.*—What maximum flexural stress may be developed in a rail under given conditions of track and loading is a matter of considerable interest. In making an estimate of the maximum stress, it will be well to start with the average stress which may be expected at low speeds for the best conditions of track, and introduce a series of factors covering the several sources of increase of variation from average stress at low speeds. Such an equation for flexural stress in the rail is

$$f = f_0 (1 + a) \quad (1 + b) \quad (1 + c) \quad (1 + d)$$

$$= \left\{\begin{matrix}\text{average stress}\\ \text{at five miles}\\ \text{per hour}\end{matrix}\right\} \quad \left.\text{spread factor}\right\} \quad \left\{\begin{matrix}\text{lateral}\\ \text{bending}\\ \text{factor}\end{matrix}\right\} \quad \left\{\begin{matrix}\text{condition of}\\ \text{track}\\ \text{factor}\end{matrix}\right\} \quad \left\{\begin{matrix}\text{variability}\\ \text{factor}\end{matrix}\right.$$

These factors have already been discussed to some extent. The average stress at five miles per hour would depend on the locomotive loading and the nature of the track (rail, ties, ballast, etc.). For the "condition of track factor" the presence of low spots, defective ties, and other imperfect conditions must be considered and, even on fairly well kept track, this factor will need consideration. The Committee plans to discuss in another report the magnitude of maximum stress for various conditions of track and loading. It is evident that the maximum stress which may be developed in the rail under usual conditions of track and traffic may be much higher than the average stresses found for best track at low speeds, and that speed factor, lateral bending factor, condition of track factor and variability factor should be recognised in making an estimate of maximum stress to which the rail will be subjected.

COLLOIDAL PHENOMENA AND THEIR SIGNIFICANCE TO THE STRUCTURAL ENGINEER.

BY

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There is always a conflict between the old and the new and it is well that it should be so, because conflict means struggle and it is only through struggle that the golden Truth is born and started on its life of service. There is no reason why the struggle for the acceptance of the theory of colloidal behaviour should have been an exception to this universal truism.

A struggle there has been—a struggle there will continue to be: inside the ranks of colloidal investigators chiefly a struggle as regards matters of detail, outside unfortunately as regards facts, which have been well established, but which are none the less denied through insufficiency of definite information.

It is not so long ago when Chemistry was developed from Mediaeval chaos and superstition to become a modern branch of Science. That some of the founders of this Science were unable to see clearly centuries into the future is not a charge against their genius. Their task to bring order out of a mass of apparently unrelated material was indeed great and they did it well.

But even these men, specially Berzelius and later on a few others, including the great Faraday, were pursued by memories of strange phenomena that their own theories were not sufficient to explain. Had they been living to-day there is no doubt that they themselves would have been the first to admit the insufficiency of their early ideas and to accept the new theories. But such is the spirit of conservation and of loyalty to the past—and a very useful spirit it is in preventing a progress which is too fast and may carry us beyond sound limits—that some adherents of classical Chemistry —not necessarily Chemists, but working in related branches of Science—are not yet ready to surrender.

At least so it must seem to a layman, who has been watching the alternate and antagonistic claims and statements of the Michaelis and le Chatelier Schools in regard to a well known and

fundamental problem of practical Chemistry, viz. the hydration and hardening of fused and powdered silica in a slightly calcareous water.

Even before the time of Graham it was known that solutions behaved differently. Some diffused through a parchment, others separated and left a sediment that would not pass. Yet the two might appear the same; both equally clear before filtration or dialysis. Graham noticed that all of the first class under suitable conditions deposited as crystals whereas the second settled as glues; he therefore established a classification, later on proven to be artificial of "Crystalloids" and "Colloids."

It became Graham's big task in life to make a special study of colloids. Later years have seen other big investigators, such as Freundlich, Zsigmondy, Ostwald, Donnan, Svedberg, and Loeb.

Graham established the term "Sol" for "Colloidal Solutions," and this term has now been universally accepted. He also established the term "Gel" for the glue like coagulations and solidifications of the sols.

The sols from the modern point of view are suspensions or emulsions of a "disperse phase" in a "dispersion medium." These two phrases and many others we owe to Ostwald. The "dispersion medium" is a continuous, homogeneous aggregation or molecules, usually, but not necessarily, a fluid, most frequently common water. The "disperse phase" is a non-continuous collection of particles, which, to produce colloidal behaviour, must be submicroscopic in size with a correspondingly increased surface area and surface energy. On the tremendous increase of surface energy for submicroscopical subdivision many of the apparent deviations from ordinary chemical behaviour seem to depend. If the disperse phase is solid the sol is called a "suspensoid," if it is fluid, an "emulsoid."

The conditions and methods necessary for the creation of gels through processes of condensation and dispersion must be omitted entirely from this paper, but the universality of colloidal existence as well as its significance for human life should be emphasized. The human body is a typical representation of many different kinds of gels. The soils we cultivate are the disintegrated remains of gels, which have become granulated from the rocks by a process of weathering. Big parts of the mountains on which we dwell, or to which we cast our eyes with longing and desire, are gels, either natural or metamorphic or at least through sedimentation. The cells of the timbers we use for our dwellings and the fibres and dyes in our clothes are colloids. The food we eat are colloids in a variety of shapes. Iron and steel are chiefly colloids, as are, with a

few exceptions, the stones and bricks of our masonry walls. Our protective paints are suspensoids or emulsoids. The clouds and fogs in our skies, the silting and scouring in our rivers are colloidal processes. It is only recently that these colloids and related colloidal processes have been made a subject of serious and systematic study.

It is not that our investigators have not seen the need of serious study, but rather that technique and instruments have not been sufficiently developed. It was only in 1909 that Siedentopf and Zsigmondy invented the ultramicroscope, with the parabolic and ultra condensers soon to follow. All previous work had been done in very primitive ways. With an ordinary miscroscope one can measure down to 200 millionths of a m.m.: while some colloidal particles are larger than this, most of them are very much smaller.

Most of the gels in nature are formed by the aid of water as a dispersion medium. These are called "Hydrogels." In the solidification process both the dispersion medium and the disperse phase, or in other words both the water and the colloidal dust solidify (more or less) into an apparently homogeneous substance. If the conditions are unfavourable there may be floculation or coagulation only: if they are favourable there will be solidification even as far as to definite fixation of form.

From an engineering point of view it is significant that a very large quantity of water may be absorbed by the colloidal dust in the formation of a gel and that a big portion of this water may be rejected shortly after the gel has set. The velocity of coagulation seems to carry all into solidification, but only a part of the water may be required for colloidal balance, and the excess is then automatically rejected. A gel will then—and specially if the water has been in excess—shrink and crack and fall to pieces, until it becomes thoroughly balanced or "dry."

Should the hydrogel be of the kind that assumes definite form this rejection of water and subsequent shrinkage will be specially noteworthy; it would mean the crumbling and disintegration of solid substance, such as the magma of a rock or the mortar of Portland Cement.

The colloidal balance as regards water contents of a hydrogel would seem to depend on two factors: The presence of water or moisture and the vapor pressure or temperature. Should balance in this matter not exist it will be automatically restored as far as existing conditions will permit. We have already noted that excess water will be rejected; should a deficiency exist water will be absorbed. The limits of variability on this point are very far

apart: only a small increase in temperature will cause a great increase in vapor pressure and a correspondingly increased absorption of water.

When a gel absorbs water it increases in volume but not to an equal extent to the volume of the added water; internal stresses must therefore occur, also production of heat. Both have been experimentally established. The rejection of water follows a slightly different curve and the phenomenon as a whole is subject to hysteresis.

Hatschek quotes Reinke as having made Œdometer experiments on Laminaria cells and shown by direct readings over 40 atmospheres pressure for a 16 per cent. swelling. White experimenting on 1 to 3 Portland Cement mortar has shown elongations of 0·15 per cent. corresponding to a stress, if the restraint were complete, of not less than 1,500 lbs. per sq. in. In addition to this there is the stress due to internal restraint by the colloidal structure.

By natural or artificial means a hydrogel may be made to reject water until colloidal balance has been attained. A Silica gel precipitated by the presence of calcium oxide in water will produce a colloidal calcium hydro silicate. According to Michaelis this is the fundamental hardening substance in Portland Cement and related products, which during a process of rejection of excess water becomes dry and hard and fixed.

From the view point of Natural Philosophy or Pure Science there are an almost endless variety of phenomena that might be studied in connection with sols and gels. From the view point of structural engineering only two of them, already referred to, are at present specially significant and important, viz.

1. The setting of certain gels into fixed bodies of definitely established shapes and sizes.

2. The change of the water contents of these fixed gels and in connection therewith changes of volume and temperature.

The semifluid gels are of great interest to the chemical engineer and specially so the changes of water contents of these gels; they are of even more interest to the biologist, but the structural engineer in an elementary study may confine himself to the above two phenomena.

To review in detail all the more common structural materials from the view point of colloidal behaviour would be both instructive and interesting. But this unfortunately cannot be done in this paper. Space does not permit and the facts are difficult to ascertain. The biologists and the manufacturers are those who have been

primarily served by the colloidal investigators; for the structural engineers next to nothing has been done.

We must turn to the Geologist for auxiliary information, and he, unfortunately, does not seem to be a colloidal enthusiast. He expresses himself in terms of classical chemistry while his domain is full of colloidal facts. His terminology is significant: it is very much his own because Geology in one sense is an old science, but it synchronizes beautifully with colloidal theory. "Sedimentation" expresses a well balanced hardening of a gel--with or without organic or inorganic impurities. "Intrusion" and "Extrusion" expresses the flow and distribution of gels while they are still fluid or semifluid and before the conditions become favourable for hardening. The "Magma" is almost a colloidal phrase: it is the geologist's word for a hardened gel and "weathering" is at least one half, if not more, the process of colloidal absorption and rejection of water with its destructive strains, stresses, and temperature variations. Clouds and fogs and silt belong almost without change to colloidal phraseology.

Clark according to Ries and Watson gives us the following information about the prevalence of the elements in the Earth's crust.

Silicon	27·74%
Aluminim . .	7·85
Iron	4·50
Calcium	3·47
Oxygen	47·33
Hydrogen	0·22
Miscellaneous	8·89
Total	100·00%

A rough estimate of this sort would seem possible, but the decimals in this table arouse suspicion: there seems to be far too much refinement. We would also wish to know the depth of the Earth's crust. This is at best doubtful, and unless perfect uniformity is assumed—and this would hardly be permissible—the results would be very approximate. The Hydrogen contents seem to be low; Hydrogen is very light and the figure would be low, but it is more likely that both crystallic and collodial water has been omitted. Assuming, however, a rough reliability as regards proportions it impresses us specially that Silicon is so over abundant.

Colloidal Hydrosilica Gels have been extensively investigated, presumably because during conditions of incomplete technique they

were easy to produce. Nature produced them also in abundance, possibly for the same reason. Quarts with its numerous relations and combinations, such as Flint, Granite, and Gneiss are natural examples. Portland Cement mortar and concrete are other examples of artificially produced compositions.

Sand stone and Lime stone are other examples: Sand stone a metamorphic rock built up from the ruins of siliceous Gels and Limestone a gel of calcareous origin. Clay, another product of special interest is a gel of Alumina.

While the above are mentioned it is not denied that the various component parts do not occur as Crystals and Anhedrons; it is merely claimed that the principal occurrence is in colloidal condition. The Earth's crust has been a Colloidal Laboratory of vast dimensions.

It is characteristic of all the above rocks and minerals that they should occur as fixed or at least as solid gels, either as a homogeneous mass or as an aggregate in a heterogeneous mass in which another gel forms the cementation material.* In the latter case the aggregate is not always all gel, a smaller or larger part may be crystals, and crystals may also settle out in the formation of the cementation substance, particularly if Magnesium, Aluminium, or Iron should reverse their polarity and act with calcareous water. In all cases, however, the gels retain their faculty to absorb or reject water, to expand or to contract due to this change of water contents, and to produce or absorb heat accordingly.

Michaelis many years ago in his investigation of Portland Cement pointed out that excess water causes a considerable amount of shrinkage and destruction. Other gels behave very much in the same manner. Should this initial danger of destruction have been avoided subsequent change of water contents remains as a secondary and very substantial danger.

The Colloidal water is distributed over the mass through macroscopic, microscopic, or submicroscopic capillaries in the body of the gel. The nature and method of final fixation on the sub-microscopic colloidal dust of the original sol is related to the colloidal structure of the gel, and about this, as about the structure of the atom, apparently very little is definitely known or at least published so as to be available for a layman.

The shrinkage of the gel leaves the crystals unaffected; adjacent to these, therefore, there develop special clearances which unfortunately may be macroscopic in size and serve as special and ample paths for the water both for a rapid rejection, and later

on for absorption, when the pressure and temperature conditions have been reversed. This is a special danger in building stones, and also in Portland cement concrete.

Manufactured iron and other metals are also colloidal in nature—their structure is denser and collodial investigation, therefore, at present of relatively less interest. Microscopical investigations of these materials have been carried on for years and their structure is well known.

Timber cells are colloidal and colloidal behaviour of timber is very significant. Much material is available from colloidal bio chemical investigations. To review the same in this paper would carry us too far. A special paper would be required to do justice to the subject.

Water is the life of the Tropics, and also the cause of the destruction of its man-made creations and the metamorphosis of its rocks and soils. Colloidal theory seems to explain most of this destruction and change. The wet monsoon comes; everything colloidal absorbs water and swells. Then comes the dry season: the water is rejected, the structure contracts. This is the process every year, and affects practically all that is built by man and much that is built by Nature. Fatalism in the meantime has obtained a hold on man's mind; one surrenders to the law of decay and destruction: there seems to be nothing else to do.

Is it really necessary to surrender so completely; has colloidal theory nothing to teach us in the matter of defence? One thing seems to be plain enough, namely, that waterproof protection should be applied on all exposed structural materials whenever conditions will permit. This means ordinarily the use of specialised, high class paints, formulated to give the best protection for the exposed materials under the most trying conditions of monsoonal change. It is merely elementary common sense, although very often neglected for the sake of economy, and yet at great expense.

There are other lessons we may learn, and these we learn by the study of building stones of special composition and density. Some of these seem to leave no entree for the water; nay even more, they reject water from the surface. As far as natural stones for building purposes are concerned the problem then seems to be simple; it is a matter of selection only and it would be except for the matter of cost. It might become necessary to select a semi-permanent stone and subject it to proper protective treatment. When it comes to artificial products, such as concrete, it is a matter of limitation.

All exposed concrete above ground should be surface treated at least, so as to cause it to reject the water of the monsoon. Structural concrete is monolithic for an entire building and this makes the stresses due to change in water contents specially dangerous, because each element is restrained by rigid attachment to the rest of the structure. In this respect change of water contents is even more dangerous than change of temperature. Below ground, as in foundations and foundation walls, and even above ground, as in retaining walls, dams, and bridges--preferably the whole mass of concrete should be made impermeable. Not in the light-hearted sense that so many engineers interpret this word: "watertight against percolation," but truly impermeable.

Concrete by proper care and without special preparation can be made watertight, but not impermeable. It may be "watertight" and usually is -through colloidal absorption and swelling, but this swelling is far from beneficial for the concrete. On the contrary repeated swellings and alternate contractions with resultant strain and stress will slowly destroy the concrete; the free water in the mass will also corrode the reinforcement and thus create heavy internal stresses, both of which are very undesirable and dangerous. Impermeability means something more than watertightness; a concrete so tight that nothing but the surface should be affected by colloidal absorption of water, or better yet a concrete with submicroscopic pores only and negative capillarity, so that all water would be rejected before having a chance of entering. No amount of ordinary care will produce this concrete: special means must be adopted for internal waterproofing. The world for years has been searching for these special means and they have been discovered.

Before success was finally achieved several materials and methods were proposed and tried. Chemically active materials evidently were out of the question: they would interfere with the well known properties of cement and introduce danger and uncertainty.

Inert materials would also be dangerous and at the same time wasteful and inefficient. They would close the pores in part only; the reduction of water absorption in the cement gel would not be sufficient to prevent slow destruction. In case of an excess of inert filler the structural value of the cement would be destroyed; unfortunately there would have to be a great deal to make it effective.

There was then little else to suggest except some suitable colloid The unsaturated colloids looked promising. They would act with the Calcium Oxide and form elastic self-hardening gels

which would close the pores. True, but this would be almost equal to a chemical reaction and therefore dangerous: what guarantee would there be that the structural value of the cement would not be lowered or destroyed. Organic acids ready to form alkaline soaps or partial colloidal developments of these materials were in this class and were soon proclaimed dangerous.

The metallic soaps proved to be a better selection; they are a finished colloidal product before being placed in the concrete or the mortar. They respond quickly when touched by water, but only within narrow limits so that the pores are therefore--without undue internal pressure—closed by this supplementary colloid even before the water has had a chance to act upon the cement gel.

This clearly is a solution of the right kind, but one more safeguard seemed to be desirable: namely, the reversal of the capilarity so that the water would be repelled at a mere contact with the structure. A great deal to ask, because water is needed for the mixing, and yet after setting it must be repelled. It would be interesting to know how this is done, but the manu facturers refuse information.

With the double safeguard of reversed capilarity and a special colloid to close the pores the moment water begins to act cement concrete or plaster would seem to be well protected. By a double gate each pore is closed, and after the excess water has once been rejected it has no chance to enter again on its evil task of destruc tion.

In presenting this paper the author does not wish to pose as a chemist, and nothing contained therein is claimed as original. My own special field is chiefly structural mechanics. The subject of colloidal behavior is important, however, and the information available both scant and scattered. It has been my aim and pur pose to review the field and collect such data as has seemed useful for my profession. In doing this I have had no desire to step into another man's domain. The colloidal chemists have left the structural engineer in almost complete ignorance of such colloid theory as concerns him most intimately and he is therefore forced to go in search of information.

JAMSHEDPUR SEWAGE DISPOSAL WORKS

WITH

SPECIAL REFERENCE TO THE ACTIVATED SLUDGE PLANT.

BY

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When the Tata Iron and Steel Works was first installed at Jamshedpur, or Sakchi as it was then called a sewerage system was constructed to serve the town as then laid out. The sewerage system was divided into two parts, one on either side of the ridge astride of which the town is built. Each part consisted of a set of main sewers leading from water flushed latrines with dumping pits to disposal works. There were no house connections. The house service was entirely by hand to the dumping pits. Each disposal works has a small screening chamber at the end of the sewers. After passing the screening chamber, the sewage flows by a distributing channel to one or more of four septic tanks. These septic tanks, as originally constructed, were simple oblong tanks without any cross walls or baffles of any kind, except a scum board near the inlet and outlet. The effluent from the tanks flows through two dosing syphons on to two filters. The effluent from the one disposal works comes through a long *nala* into the river and from the other is partly used on a farm and part runs down another *nala* into the river. In 1916 Col. Clemesha inspected the disposal works. As it was already probable that the works and consequently the town would shortly be enlarged, he suggested that the Steel Co. should investigate the possibilities of the activated sludge process for dealing with the sewage of the enlarged town

and even as a substitute for the disposal works already in operation. He recommended that Dr. Fowler should be consulted, and on Dr. Fowler's recommendation a series of laboratory experiments was instituted to study the behaviour of the sludge under Indian conditions, particularly at Jamshedpur where the hot weather temperature is very high. In the meanwhile, Messrs. Jones & Attwood of Stourbridge (now Activated Sludge, Ltd.), to whom reference was made, furnished proposals for converting the existing septic tanks into activated sludge tanks. In 1917 one of the writers, V. N. Sarangdhar, was engaged by the firm and deputed to Bangalore to study the activated sludge process under Dr. Fowler. Early in 1918 he was called to Jamshedpur to study the Jamshedpur sewage and its behaviour when treated by the activated sludge process. Experiments on a small scale were started in April and it was found then that in spite of high temperature in the months of May and June, the sludge purified the Jamshedpur sewage quite satisfactorily. A report on these experiments was prepared and submitted to the Company. At the same time the other writer—F. C. Temple—was sent by Government to advise on the general sanitary needs of the enlarged town. As a result of that first visit, Dr. P. K. Mukerjee was engaged as Health Officer of the Company and took charge of the sewerage system including the disposal works. These latter were not giving satisfactory results at the time, and as investigation showed that considerable over-septicisation was occurring, two septic tank compartments in each of the disposal works were put out of action with immediate improvement in the working of the system. At the same time some very peculiar filters, shown in drawing No. 2 which were apparently intended to further oxidise the effluent from the main filters, were abolished, because the effluent from them was invariably worse than the effluent from the main filters. It is possible that if time had been available for a full investigation of their properties these filters might have been made effective, but there was so much to be done at the time that when a reasonably good effluent was obtained from the main filters every one was glad to be content with that. Considerable detailed investigation proceeded until November 1918, when a conference was held, which was attended by Dr. Fowler, and it was then decided that it would be better to construct a new activated sludge plant, which would take over the work of one of the old disposal works, and also an additional area of the town then being constructed, than to remodel the old disposal works, for it was obviously desirable to remove both of the old disposal works from their existing situations. Investigation elsewhere also had modified ideas regarding the design of activated sludge tanks and the ridge and furrow bottom tank proposed by Jones & Attwood for the

conversion of the old septic tanks had already been superseded by the wagon bottom.

With a view to designing the new Activated Sludge Plant, gaugings were taken for a considerable period in the sewers already constructed and in operation, which were to be connected to the new system, and in the open drains, which removed kitchen sullage, bath water and the like, which were also to be connected into the system, and an estimate was made of the discharge to be expected from the additional area to be sewered.

The existing main sewer was found to flow at an average rate of 72,000 gallons per day and the surface drains to be connected into it at 11,000 gallons per day. The population served was about 3,000. It was decided to collect this sewage in a well, capable of holding 12 hours' flow, designed as a grit catcher with a screening chamber at its entrance, and to pump the sewage on to the ridge already selected as the site for the disposal works, at a distance of some 6,340 feet from the well and 73 feet above it. This informa tion was supplied to Messrs. Jones & Attwood, who were asked to design a plant, which could be incorporated as part of a larger plant to serve the whole town when and if its population should increase to 50,000 or even 100,000. In reply to this enquiry, Messrs. Jones & Attwood wrote as follows:—

" We note you require us to put forward a plant to deal with " a sewage flow from a present population of 3,000 at 38 gallons " per head and a flow from a future population of from 50,000 to " 100,000. Thus the future flow will be from 17 to 34 times the " present flow. If the tank you now ask us to design is to be a unit " of a plant to deal with the sewage from 100,000 population then " there will be 34 units in operation besides standbyes.

" You also ask us to put forward the most economical unit and " we find that the larger the unit the more economical it is, thus we " should not propose more than 10 units for the 100,000 population.

" Enclosed is print Drawing No. 4 showing a complete plant, " also a description with parts numbered to suit numbers on draw- " ing.

" You will note that a re-aeration tank is shown and it has been " found advisable to have a certain amount of re-aeration in all " plants as some de-activation takes place in the settlement tank.

" Hence our proposal is that the tank now suggested for the " 3,000 population should become a re-aeration tank in final per- " manent plant in which case its size and proportion need not be " those of an aeration unit of final plant.

" For convenience in testing we propose 3 units each to deal with " 50,000 gallons per day assuming a 6 hours' aeration period of 4 " fills per day.

"If capacity is insufficient the tanks can be lengthened: if too "great one or even two units can be put out of commission by "leaving them full of pure or treated water.

"The settlement tank to be built for this preliminary plant can "be used later for settling the surplus sludge.

"We note you suggest two sets of screens, the first with 1″ "spaces and the second with ½″ spaces. In our designs we are "adopting from 1 8″ to ¼″ spaces for the fine screen, and we find "that rags get past even these."

The same firm sent us Drawing No. 4 to which the plant was first built. The drawing with its descriptive list is self explanatory. The details of construction offer a very few points of interest. The foundations were lime concrete including the lining of the hopper of the settling tank. The main walls were brick in lime, cement plastered, and the partition walls were made of brick on edge in cement mortar reinforced with quarter inch rods and then covered with cement plaster. The arrangement of the air mains leading to the diffusers is shown in Drawing No. 5, which incidentally shows the general arrangement of the pulsating gear, the detail of which is given in Drawing No. 7. The details of diffusers and of the Clifford inlet, through which the aerated sewage is admitted to the settling chamber are given in Drawings Nos. 5A and 6.

The sewage enters at the point where the 7″ main is shown going through the wall below the surface of the sewage in the tank in the mixing chamber marked 1 a. It passes through the opening at the bottom of the wall into chamber 2 in the direction of the arrows and flows out again into connecting chamber 3. From 3 it flows into the second aeration chamber 2 a, which is similar to 2; from there to 3 a, the second connecting chamber; from that again to 2-b, the third aeration chamber, and so through 4, the central chamber, from which it goes by pipe 5 a to the Clifford inlet in the Settling Tank 5. The sludge settles in 5 and the clear effluent is drawn off through the bell mouth outlets 5 e into the effluent channel 6: over the effluent weir 6-a to effluent chamber 6 b. There is a forward movement of the sewage through the tank due to the incoming sewage, and the amount that overflows at the end is equal to the amount that comes in at the beginning.

The activated sludge process depends upon the mixing of settled activated sludge with the incoming sewage. For this purpose air lift 7 picks up the sludge from the bottom of the settling tank through the pipe 7 a into the re aeration chamber 8. The re-aerated sludge flows out of 8-b over a submerged weir into mixing chamber 1 a where it mixes with the incoming sewage. The rapidity of movement of the sewage in its journey through the tank depends on two

factors :—(1) the amount of sewage entering from the pumps, and (2) the amount of sludge lifted from the bottom of the settling tank by the air lift through the re-aeration tank into the mixing chamber.

The blowers are two positive rotary blowers, each capable of delivering 200 cft. of free air per minute at 240 revolutions per minute against a pressure of 4 lbs. per sq. inch, arranged for belt drive. It was originally hoped that electric current would be available by the time the plant was complete, and it was intended to use approximately 7½ B. H. P. motors for driving the blowers. As, however, no electric feeder line had come within a practicable distance of the plant, such prime movers as were available on the spot were put into use. One of these is a 2 stroke crude oil 18 H.P. engine, which is still doing the work for about 8 hours a day. To keep this engine running it was very soon found necessary to have several hours free every day for cleaning and overhauling. As the blowers had to go on continuously, a vertical boiler was found, and the engine from a steam hoist adapted to drive one of the blowers. This machine ran for about a year, and then when the boiler was required elsewhere a 20 H.P. portable engine was put in its place and is still running. None of these engines are correctly proportioned for the work that they have to do and are not running at all economically. For this reason, it is to be noted from the outset that this plant gives very little information regarding the true costs of running the activated sludge process, which is and must be one of the most important considerations in determining whether any particular process is to be installed or not in any particular locality.

In consequence of the good results obtained elsewhere by its introduction, the apparatus known as a pulsating gear was installed on the air delivery system. This apparatus consists of an air driven turbine operating 6 slide valves, controlling the air supply taken from the main delivery pipe through small feed pipes to 6 diaphragm valves on the branch air pipes which lead to the diffusers. As the turbine revolves, the valves admit air to the diaphragm valves, in turn temporarily cutting the air supply off from each branch pipe and its set of diffusers. This has been found in some installations to economise in the total quantity of air required.

The actual outlet arrangement of the effluent was altered slightly from Drawing No. 4. Effluent chamber 6 b was constructed as shown in Drawing No. 8 to discharge over a 90° V. Notch on either side, with a small gauge chamber on the third side, in which, by reading on a scale, the approximate discharge at any moment can be determined. As the effluent is used to irrigate a large farm, and as a small part of the farm is at a high level, a 6″ pipe was introduced into the effluent channel 6, so as to make it possible, when necessary, to take advantage of the few feet extra head given by the height of the tank itself.

The construction of the tanks was commenced late in 1919. Owing to shipping delays the bulk of the equipment did not arrive until July, 1920, and parts of it did not come to hand until July, 1921. It was, therefore, not until near the end of November, 1921, that the plant could first be put into operation. The tanks (aeration, settling, and re aeration) were filled with sewage, and air was turned o.. while they were being filled. When they were full, the inflow of fresh sewage was stopped, so that there was no outflow through the effluent channel. Circulation was maintained through the whole series of tanks by means of the compressed air lift, and blowing was steadily continued. At the end of 24 hours sludge could be seen in traces and at the end of 48 hours' aeration sludge could be distinctly settled out in a bottle leaving a clear effluent with the following analysis :-

F. & SN.	Alb N.	Nitrite.	Nitrate.	Cl.	Sludge.
0 hrs. 0 744	0·216	Nil	Nil	2 0	Nil
24 hrs. 0 860	0 186	Nil	f.t	2 1	F. Traces.
48 hrs. 0·912	0·108	f.t	0·01	2·1	Distinct.

This was so hopeful that continuous running was attempted but various difficulties and defects, which were only to be expected in the first plant of the kind to be set to work in India, began to appear very early. It was at this stage that it became clear that the oil engine could not run the plant single-handed. The whole plant was shut down while the hoist engine was being installed: the tanks were emptied out and a number of minor alterations made, one of these being the raising of the walls of the re aeration tank near the air lift to prevent the return sludge spilling over the wall.

A fresh start was made in December. Within 16 hours traces of sludge were visible, and at the end of 24 hours sludge could be dis tinctly settled out in a bottle. So remarkable a formation of sludge within so short a period may have been due to the presence of some starting nucleus. It may have come from silt and coarse particles in the sewage itself or may have come from particles of old sludge adhering to the tank or diffusers. At the end of 24 hours' run, the condition of the tank was favourable for taking fresh sewage, and at the end of 48 hours, the tank was set to run on the continuous flow system for which it was designed. The following is the analysis of the effluent at the end of 48 hours :--

F. & S.S.	Alb N.	Nitrite.	Nitrate.	Cl.	Sludge.
0·675	0·09	0·001	0·01	1·7	1½%

It was some time before the routine of the plant was so organised that it could be relied on to run steadily for several days on end. The sewage pumped up from the well, which was intended to act as a grit catcher, contained excessive grit and silt. This was improved

by working a continuous chain bucket sludge lift at the well daily. Owing to the excessive silt and also to mechanical difficulties in keeping up sufficient air pressure from the blowers, the diffusers choked rapidly. These difficulties were overcome by degrees and it became possible to maintain a steady pressure of 3½ lbs. of air in the diffusers. Means were also found to clean the diffusers without much difficulty. For this purpose blowing steam through them was found very effective.

Whenever for any reason the tank had to be shut down, the crude sewage was turned loose on the farm, where there was ample land to absorb it. This was made possible by taking a branch, controlled by a sluice valve, off the 7″ Rising Main, at ground level, at the point where it turned up into the tank. The inlet to the tank was also controlled by a sluice valve. When the tank was first put to work, it was found necessary to regulate the flow of sewage and this was more conveniently done by opening and closing these two valves than by sending to the Pump House, over a mile away. With the 7″ pipe delivering in the tank below top water level there was a danger of discharging the contents of the upper part of the tank through the branch of the rising main on to the farm, or if the pumps shut down accidentally, of discharging them backwards down the main. It was also impossible to watch the variations of flow at the inlet both for quality and quantity. The valve on the inlet to the tank was therefore removed and the pipe lifted so as to discharge into the tank over the top of the wall. (Drawing No. 8.) Any regulation of flow necessary has subsequently been done by means of the other valve releasing the crude sewage direct on the farm. In actual practice the use of this valve has become less and less frequent, and now for months at a time it remains steadily closed. During 1922 the running of the plant settled down to a fairly steady routine, but the quantity of sewage to be dealt with steadily increased. When it reached 130,000 gallons per day, it exceeded the capacity of the tank, as designed, the water level in the first aeration chamber being raised to such an extent that sewage overflowed in all directions in an unpurified condition. Some temporary expedients used to overcome this difficulty indicated that the plant was capable of purifying a very much larger quantity of sewage than had originally been anticipated. In August, 1922, as stated above, the boiler which had been running the steam engine was required elsewhere, and it became necessary to rearrange part of the mechanical equipment so that one blower could be driven by the portable steam engine, to which reference has already been made and which became available at the same time. As the oil engine was not capable of steady 24 hours' running while the change of the steam engine was being made, and as it was in need of a thorough overhaul, it was decided to shut down the plant, while

the mechanical equipment was overhauled and re-arranged, and to take the opportunity of raising the walls of the re-aeration tank and of the first and second aeration tanks and of the bye-pass channel. Before the repairs and alterations were complete, a strike occurred in the Steel Works, on account of which no power was available for working the sewage pumps so that it was impossible to start up the plant again until November, because there was no sewage to put in it. A number of other alterations were made at that time. The air distribution system, as originally designed, gave a great deal of trouble. A radical defect for this climate was the use of rubber washers for all joints. Rubber perishes in this climate and the joints leak. All the rubber joints have been replaced by lead. The pipes were originally placed on tiny cast iron stands. The storms of the hot weather and rainy seasons with their high winds blew the air piping inches out of the straight, leaving leaks to be repaired. By this time the cast iron stands had been replaced by an almost continuous cradle of bricks and cement plaster. The pulsating gear proved a complete failure. Even when it was new it never worked well and the power saved was not appreciable. Very soon after it was put into use the large rubber diaphragms, which worked the cut off valves, disintegrated. Within two months of starting up, it was deliberately taken out of action. There were no guides for the handles of the disc valves that control the various aeration tanks and connecting chambers, and the handles could fall into the sewage. Guides were fixed to prevent this. Mechanically the blowers have been most reliable. The name plate speed is shown as 240 r. p. m. and maximum pressure as 4 lbs. It was found that the air pressure near the diffusers was only 3 to 3½ lbs. At this speed the system runs satisfactorily.

Since this re-arrangement of the mechanical equipment there has been much less difficulty with choked diffusers. This is partly due to the fact that the air pressure has not only been maintained at rather higher average pressure but has been steadily maintained at the pressure required. When the pressure was liable to drop for an hour or so, silt and sludge had time to accumulate in such quantities on the diffusers that ordinary air pressure would not blow them free. Even now when proper pressure is maintained there is still some trouble with the diffusers. It has recently been determined without any doubt that this is due to the large quantity of very fine silt sent up by the pumps, from which it is clear that though the capacity of the sump is sufficient to reduce the velocity to a point at which most of the ordinary coarse silt will come down, its shape is such that it does not allow sufficient time of travel to bring down even the whole of the mineral grit. The sewage also contains fine colloidal silt, which is common to all the upland waters of Chota Nagpur and which is known from

various water works installations not to come down even though the water is reduced to a state of complete quiescence; but which comes down instantly if a coagulant is added. In a water works alum or some salt of that kind is used as a coagulant. In the sewage works the activated sludge acts as a coagulant and brings down the fine silt with extreme rapidity in the first aeration tank.

Among other drawings that have been sent us there is one of an installation containing an aerated grit catcher. It is not clear from those drawings whether any activated sludge is admitted to the grit catcher or whether the crude sewage alone is aerated. In the absence of further information it is difficult to see how this grit catcher works and as it was not recommended for the Jamshedpur Plant, presumably it was not entirely successful. Much research work evidently remains to be done on the problem of extracting the fine colloidal silt found here. There are many forms of grit catchers in use in different parts of the world, which would extract the greater part of the mineral grit. The Jamshedpur experience indicates that this should be dealt with as a problem separate from that of extracting the fine colloidal silt. The latter can be brought down without any difficulty by the use of a little activated sludge. The danger of bringing it down in this way is that putrefactive matter will come down with the silt, and may form a septic and offensive sludge, which would have to be buried as rapidly as possible. It remains to devise a grit catcher which will bring down the maximum of the fine colloidal silt with the minimum of organic matter so as to avoid trouble in the grit catcher on the one hand and in the aeration tanks on the other. Up to the present time the best procedure that we have been able to devise is to clean out the first aeration tank, whenever the silt accumulates to an extent that interferes with the working of the tank. Another source of trouble in the diffusers was dust from the atmosphere and oil from the machine drawn in by the blowers. An air filter is installed to minimize the dust trouble, but oil trouble still remains. At periods when there has been trouble in maintaining regular and sufficient air pressure, the opportunities have been taken to investigate the effect on the sludge. It deteriorates rapidly assuming a flabby appearance, does not easily settle, and under the microscope shows a large growth of protozoa and other forms of higher life.

As in all other forms of sewage disposal works, there is a relation to be established between the number of persons served, the strength of the sewage, and the size of the tank in which the purification is effected. The experiments carried out by Col. Clemesha in Calcutta and by the Bihar and Orissa Public Health Department in Gaya and Patna showed that a suitable size of septic tank was 2 cft. of tank capacity per user of any sewage

between 5 and 10 gallons dilution. If a septic tank is designed of this capacity, the time taken by the sewage to pass through the tank, or the period of rest which is the term usually employed, will take care of itself. We have already seen that Messrs. Jones & Attwood designed the Jamshedpur Plant for the sewage of 3,000 persons diluted to 38 gallons per head, and, as they say in their letter, they proposed 3 units, each to deal with 50,000 gallons per day assuming 6 hours' aeration period of 4 fills per day.

The capacity of each of the 3 aeration tanks is nearly 12,000 gallons or some 36,000 gallons in all, together with which may be taken the bye-pass channel, making a total aerating tank capacity of some 40,000 gallons. This is equivalent to a little more than 2 cft. tank capacity per head, which agrees approximately with the septic tank practice. Expressed in terms of period of aeration, this tank capacity would give a period of some 6½ hours' aeration to the sewage when flowing at an average rate of 150,000 gallons per day, but for the fact that while the clear effluent is allowed to escape, the sludge is retained in the tank until it occupies a space of 20 per cent. of the total capacity; the actual aeration period, therefore, when the flow is 150,000 gallons, is about 5 hours.

In practice, the load on the tank has been increased whenever opportunity has occurred. It was evident in the early stages that the limit to the liquid capacity of the tank was fixed by the height of the walls, for sewage was pumped into the tank and at the same time the return sludge air lift was worked at such a pace that the surface gradient through the aeration tank became so steep that the first tank overflowed. The actual gradient at a flow of 200,000 gallons per day was 18 inches between the inlet of the first aeration tank and the outlet of the third. At the time when the mechanical equipment was being overhauled, the walls of the aeration tanks were raised and the tank made capable of dealing with a daily flow of 250,000 gallons per day, with the air lift raising 120,000 gallons per day, making a total rate of flow through the re-aeration tanks of about 370,000 gallons per day.

During one period of accurate observation the number of persons served was 6,000; the flow of sewage was 150,000 gallons per day, the dilution of the sewage was therefore 25 gallons per head per day; and the cubic capacity of the tank 1·3cft. per head. With the plant working under these conditions a satisfactory non putrefactive effluent was obtained, and a sludge which could be handled without difficulty. At the times of a maximum flow of 250,000 gallons per day there may have been occasions when the population served was 8,000, but this is uncertain. When the flow is as great as this, the settling tank capacity is not sufficient to bring down all the sludge, and light particles are to be seen in the

effluent, but no trouble has as yet arisen on this account. On a recent occasion, when No. 1 aeration tank had to be laid off for the removal of silt, the whole of the load of about 200,000 gallons per day from 6,000 people was put on to tanks Nos. 2 and 3. A non putrefactive effluent was still obtained though the tank capacity had come down to 0.9 cft. per user and the period of aeration to 2½ hours. Working at this speed and with so short aeration, the nitrification and the coagulation of the sludge is less; sludge settles much less rapidly and an unusually large proportion goes out with effluent. If it had not been possible to dispose of effluent and sludge together on the farm it is possible that the sludge and the effluent might have given rise to a nuisance. This trouble could probably be overcome by increasing the re-aeration tank and the settling tank capacity by the addition of another settling tank and possibly extending the re-aeration tank. Investigations on these lines will be of the greatest value, for every improvement of this kind will diminish the cost of the process, and its cost is at present the greatest obstacle to its installation in many places.

In a continuous flow plant, the aeration period is taken on the average: for instance, when the flow of sewage is 150,000 gallons, the aeration period is stated to be about 5 hours. The efficient working of the plant is much influenced by the rate at which the sludge is returned from the air lift into the re-aeration tank. When the sewage is from 25 to 30 gallons dilution the best admixture of activated sludge with incoming sewage is produced by working the air lift from the settling tank into the re-aeration tank at the rate of 120,000 gallons per day. This together with the normal inflow of sewage of 150,000 gallons per day makes a total rate of flow through the aeration tank of 270,000 gallons per day. The minimum time therefore in which any particular particle of sewage can pass through the plant is about 2½ hours, though the average number of times that any average particle of sewage circulates through the tank is almost 9. Working at the greater speed of 150,000 gallons per day of return sludge, the total rate of flow through the aeration tank is 300,000 gallons per day. The minimum time then in which any particular particle of sewage can pass through the plant is about 2 hrs. while the average number of times that any average particle of sewage circulates through the tank is 10.

The capacity of the re-aeration chamber is approximately 5,000 gallons, and if the air-lift is worked at the average rate of 120,000 gallons per day the re-aeration period is one hour. If the incoming sewage is very strong (as occurs at certain periods every day when the contents of night soil carts are dumped in the sewers)

the tank works better if the air-lift is speeded up to a rate of 150,000 gallons per day. This reduces the period of re-aeration, but by increasing the rapidity of flow through the aeration tank it brings the strong sewage more rapidly into an emulsion. It is to be noted that the rate at which the air lift must be worked depends much more on the strength of the sewage than on its bulk. This agrees with experience in all biological sewage disposal works that tank capacity and addition of outside re agents depend on the quantity of organic matter to be purified or in other words on the number of persons served.

The design of the re aeration tank is not satisfactory. From the drawing No. 4 it will be seen that there is no arrangement provided to let the surplus sludge off. This is now done by a syphon. (See photo.) The mushroom valve provided to drain the tank is not a convenient arrangement to let the sludge off daily, as it was found that some fine mineral silt always lodged between the valve faces and prevented the valve from closing tight. Another defect in the tank is the connection between the mixing chamber and the re aeration tank. The principle for which the re aeration tank stands is vitiated by the fact that if for some reason the air lift stops working, the sewage, instead of moving forward through the aeration tank in the direction of arrows shown in the drawing No. 1, short circuits through the re aeration tank into the settling tank and then passes out in unpurified condition. This not only deactivates the sludge but disturbs the biological cycle for a long time. If sewage is made to pass through the aeration tank even if no air is coming through the diffusers, it does not cause so much disturbance (and in fact the effluent is not bad, for some purification goes on) as it does when it passes out through the re-aeration tank. It is proposed to remedy this defect by disconnecting the re-aeration tank entirely from the mixing chamber and raising its walls so that the return sludge will fall over a weir into the mixing chamber. This would not only give better mechanical and biological results, but would make it easy to determine the precise rate at which the re-aerated sludge was being returned into the incoming sewage. At present when the flow of sewage is over 150,000 gallons per day, a portion of the re-aeration tank acts also as a mixing chamber, for the backward flow of the sewage causes a whirlpool and reduces the capacity of the re-aeration tank.

In order to arrive at an intelligent comparison between the working of the activated sludge plant and that of other plants elsewhere we have been studying the ratio of air to sewage. When the volume and strength of sewage is such that the tank capacity is 1·3cft. per head, 1·2 cft. of air per gallon with a minimum of 4 hours'

aeration purifies the Jamshedpur sewage to the standard recommended by the Royal Commission.

As noted above, before any large scale experiment on the preparation of activated sludge and purification of sewage by its agency could be carried on in Jamshedpur much precise information was collected in the Laboratory by means of small scale experiments in tubs of a capacity of 3 litres and 30 gallons each. As the Activated Sludge is a biochemical process fostering aerobic bacteria the sludge produced had to be kept aerated by introducing air. For this purpose a supply of compressed air was obtained and the first culture of the Activated Sludge was prepared by putting raw sewage in the tubs and blowing air through them. When a trace of nitrification was seen, air blowing was stopped and the whole mass of liquid allowed to stand quiescent for one hour. Supernatant liquid was drawn off leaving only 10% of the original volume which at the start contained sludge only in traces. Every day the requisite amount of sewage was put in twice and was blown in contact with the resultant sludge for 11 hours and then the whole mass allowed to settle for one hour. The supernatant clear liquid was then drawn off leaving behind the sludge which grew in bulk with every addition of fresh sewage. When sufficient sludge had been collected 20% sludge and 80% sewage were mixed together and air blown through them, and it was found that 6 hours of aeration was the time required to purify Jamshedpur sewage which was purely domestic, yielding a clear and stable effluent and a sludge healthy in appearance, free from any offensive smell and full of nitrifying bacteria. On these results recommendations were made that Jamshedpur sewage would need 6 hrs. aeration. (Cubic capacity of tank per user was not then taken into consideration.)

During these laboratory experiments longer aeration produced a better effluent and reduced the number of bacteria of B. Coli and denitrifying group; but, as in practice, the running costs would be proportionately greater, the minimum necessary period of aeration was recommended. It was also noticed that the absolute minimum period of aeration for strong Jamshedpur sewage was 3 hrs. At this figure the sludge lost some of its capacity of nitrification and settling rapidly but otherwise maintained its capacity of producing a clear effluent. Analysis of sewage and effluent was as follows:—

	3 mts. O	4 hrs. O	F. & SN.	Alb N.	No_3N.
Raw sewage	3.81	10.71	2.8	2.4	
Effluent 4 hrs. A. E. ...	0.32	0.95	f.t.	0.08	1.8
Purification %	91.6	91.2	—	96.3	—
11 hrs. A. E.	0.24	0.77	—	0.033	3.0
Purification	93.7	92.7	—	97.4	—
Raw sewage	6.05	16.99	2.74	3.3	—
Effluent 11 hrs. A. E. ...	0.53	1.25	0.02	0.06	2 2

These results were obtained by maintaining sludge at 20% to 25% volume. Increase or decrease in the sludge by large volume affected the results but not to a very appreciable extent. The above proportion of sludge was found to be a good working proportion. These experiments were conducted on a fill and draw system and continued over a period of 12 months through all the extreme changes of weather and temperature met with in Jamshedpur, and results indicated that they had no adverse effect on the sludge.

We wish here most emphatically to recommend that whenever possible such small experiments should be conducted before any large scheme is put in hand as they would give much valuable information for designing large plant and would add to the knowledge of operating the various vagaries of the sludge. We find here a very close agreement between the results obtained in these experiments and those obtained in the big plant now working on a continuous system.

The big tank designed by the Activated Sludge, Ltd., was ready to run in November 1921, on a continuous flow system. Though sludge formation was quick and purification of sewage was quite satisfactory it was noticed that sludge was not as healthy as it should be. The nitrification was defective due to defective aeration, which was caused by the frequent mechanical breakdown. The defects in the original design which affected the bio chemical factors, chief among them being denitrification, have been rectified. The operators were trained to distinguish a good sludge from a bad, and to maintain the good quality of the sludge in the tank. Analysis had to be taken twice in a day to understand the working of these tanks at various points and to enable us to collect data on which to base a routine for operation.

It is very difficult to define the characteristics of a good sludge in precise terms, and little more can be done than give descriptive notes. A good sludge should be chocolate brown in colour, free from appreciable offensive smell, and when quiescent should settle within 15 minutes. The supernatant liquid should be clear and non colloidal, and on analysis should show nitrification. If nitrates are present the sewage has been well blown. A well blown sludge under the microscope is found to be full of bacteria and to contain a few protozoa. Among the bacteria present, those that form nitrites and nitrates are the most important, and should number 100 or more per c.c. of the effluent.

When the sewage is underblown, either because the capacity of the tank is too small to allow a sufficient period of aeration, or because of mechanical trouble, or obstructions in the diffusers, the sludge deteriorates. It gives off an offensive smell, changes from a chocolate brown to a dark black colour, and takes a very long

time to settle. At the same time the supernatant liquid, instead of being clear and transparent, becomes colloidal and sticky. Sometimes a sludge assumes a texture known as "ropy." Under the microscope such a sludge shows a large growth of protozoa, very sluggish in movement, and not so active as those in a healthy well blown sludge. Unhealthy sludge may temporarily produce a satisfactory non-putrefactive effluent. But if the cause of the deterioration is not removed, a serious breakdown of the whole process will occur.

When the sewage is overblown which occurs when the quantity to be treated is too little for the tank, the sludge burns out and diminishes in volume, and the effluent becomes colloidal.

On the occasions when the sludge has been unhealthy it has been found to contain even worms such as Nematode, Chironomus, and Dero. Among the higher organisms usually found in a healthy sludge we have identified ciliate protozoa such as Vorticella, Euplotes, and Coleps, non ciliate protozoa such as Amoeba and a few rotifers such as Philodina. Whether their presence is beneficial or not it is not yet possible to say; but in a healthy sludge they have always been present in small numbers, and their movements very active.

The process of sludge formation is as follows: When the crude sewage comes in contact with a nidus of activated sludge, the colloids coagulate after a certain period, and precipitate, forming sludge. This sludge as it is first formed is not capable of purifying sewage, nor is it valuable as a fertilizer for it has an offensive smell, and being colloidal is likely to damage soil. It must be further blown until oxidization of carbon and oxidization of nitrogen bring it to the proper texture and condition. The effect of aeration can very well be studied from the analyses attached (page 73) where the difference between the analysis of the effluent after 4 hrs. aeration and after 11 hrs. aeration is apparent.

It has been established that there is a minimum and a maximum period of aeration for any particular sewage. There is also a minimum and maximum percentage of sludge to be introduced in the sewage if a clear and stable effluent is to be produced. In both relations there is a wide margin within which good results will be obtained. For Jamshedpur sewage the volume of sludge to sewage can vary safely between 10 and 20 per cent. It took some time to ascertain these figures, and still longer to regulate the working of the plant so as to obtain them.

Theoretically the aeration period when the plant first started was 12 hrs., yet the sludge was not satisfactory. This was mainly due to choking of diffusers in the middle of the tank forming convenient pockets in which denitrification and in some places even

an-aerobic septicisation took place. As soon as the difficulties were overcome and a sludge obtained of such a condition that it produced an effluent equal to the standard recommended by the Royal Commission, more and more sewage was taken until the aeration period came down to 6 hrs. It was then found that the capacity of the tank could with very small alterations be increased above 150,000 gallons per day. These alterations which have already been described enabled the plant to purify 250,000 gallons per day conveniently: to treat sometimes as much as 300,000 gallons per day without seriously affecting the quality of the sludge or the effluent.

The analysis of the sludge and data regarding quantity available from 1,000,000 gallons of sewage and nitrogen contents in the sludge are all attached in the tables.

An attempt was made to study nitrogen-fixation, but owing to difficulties in proper sampling and to various laborious and troublesome laboratory technique, the results obtained have been very contradictory. All that could be proved is the presence of nitrogen-fixing bacteria in the sludge, but whether nitrogen fixation from air takes place in a big continuous flow tank is questionable, and the chances are that on account of defective aeration, denitrification is likely to take place resulting in loss of nitrogen. At present we can account for only 80% nitrogen of the sewage: the other 20% is lost to the farm.

Some experiments were made on drying the sludge in the sun. It was found to dry very well on turf provided the depth of the sludge layer did not exceed 3 inches. Drying on sand was found unsuitable, because though the sludge dried rapidly it penetrated the upper layers of the sand which became incorporated with it, thereby lowering the percentage of nitrogen per volume of dry sludge. A 3″ layer of sludge dries on turf to spadable condition within 6 hours and within 24 hours it is quite dry in flakes, varying from 1/12th to 1/8th of an inch in thickness, which can be easily handled. In 3″ layers it dries well on a cement floor. The sludge dried on the turf and on the cement surface of a roof kept in a stoppered bottle for the last two years shows so far no sign of deterioration or of any offensive smell. The sludge as it comes out of the tank is very dilute and as much as 50% of supernatant water by volume can be removed. The remaining thickened sludge contains water as high as 99·9%, and it is therefore necessary to introduce a thickening chamber in the installation if sludge drying experiments are to be undertaken on a large scale. The maximum layer of such thickened sludge that could be dried in the sun with convenience was found to contain an inside core of offensive and putrescible matter which could not stand keeping and storing for any length of time. These cakes took 48 hours to dry completely and that too not without any

offensive smell. A well-blown sludge could conveniently be dried in the sun up to 6″ layer, and it is not advisable to push beyond that. A 3″ layer is the best and least troublesome method if ample space is available.

The value of sludge as a fertiliser can be seen from the following agricultural experiments conducted over two years.

In the Laboratory experiments mentioned above it was found that the rate of sludge formation would be 2,670 lbs. of dry matter from 1,000,000 gallons of average Jamshedpur sewage. The nitrogen content in the Laboratory dried sludge was found to be 5·1% to 6·5% depending on the amount of aeration the sludge had received.

When the large scale plant was started towards the end of 1921, and when it had settled down to good and reliable working, these experiments were again repeated and the following results were obtained. From 1,000,000 gallons of sewage 2,500 lbs. of dry matter were obtained by drying the resultant sludge. This figure is in close agreement with the one obtained in the Laboratory experiments and has been found to be almost the same these last three years. The nitrogen figure in the dried sludge was found in the beginning to be as high as 6% to 8%, and the probable explanation of this high content of Nitrogen in the sludge is that in the beginning, on account of the defective aeration referred to above, we did not obtain proper sludge for a long time, and the sludge that was produced was one which had just passed the "clotting stage" and reached the "oxidation" stage. This sludge needed further aeration to produce the right quality, but because of defects in the plant this stage was not reached. However, as noted above, the sludge was quite capable of producing a clear and good effluent and was free from any offensive smell.

All the effluent and sludge produced by the tanks are absorbed on an adjacent Dairy Farm land measuring about 30 acres (nearly 1,000 acres are available for extensions of the plant when more sewage shall be available). From the plant they are led by kutcha nalas to various fields. In 1921-22 season most of these 30 acres were brought under cultivation for the first time, because the land, which is in the nature of hard gravel soil (known as moorum), was rejected by all the indigenous cultivators as totally barren. By the application of sludge, which supplies organic humus and nitrogen, and by irrigation with the effluent, the soil has slowly changed its texture. Even in the first year the yield of barley and oats and various marketable crops was admirable. These plants were growing in very poor condition but improved within a fortnight after the application of the liquid sludge after which a healthy and vigorous growth was visible. In 1922-23 it was noted that the texture of the soil had considerably changed. The sludge application kept the

land supplied with the necessary stock of nourishment for the plants with the result that in one particular plot four crops, namely, oats, maize, beans, and cabbages, were raised within the period of one year.

The yield and growth of various crops such as maize, beans, sugarcanes, oats, and market vegetables such as cabbages, cauliflower, brinjals, peas and other varieties have been quite satisfactory. The sugarcane was grown on good paddy land, the yield being as follows:—

Class of Cane.	Weight per acre.	No. of canes per acre.
J. 21 (thin)	120,000 lbs.	51,900
New Guinea 22 (thick)	108,000 lbs.	27,600
New Guinea 15 (thick)	76,060 lbs.	15,300

These results were obtained over an area of a little over three acres and may therefore be accepted as practical and not mere hot house figures.

A series of experiments was made to compare the efficiency of sludge as a fertilizer with other natural and artificial fertilizers. A piece of land was selected which had been left uncultivated because it was looked upon by the indigenous cultivators as utterly barren. (See analysis of soil.) The land was laid out in two rows of 5 plots to each row. Between the two rows a path 5 ft. wide was left, and between each plot a bund was made 2 ft. wide and 1½ ft. high. The area of each plot was 1/10th of an acre. One row of five plots was irrigated with water supplied from the Town Mains; the other row of five plots was irrigated with activated sludge effluent. The plots were manured as shown in the Table 5. The activated sludge being liquid was distributed by making small channels in the plots. The sludge was dry in a little over 24 hours and when quite dry was mixed with the soil by ploughing. During these operations there was no nuisance of any kind. In plot No. 8 the sludge was supplied on 7-12-22 and in plot No. 7 on 9-12-22. Cowdung and ammonium sulphate used in other plots were applied on 9-12-22. As it was late in the season, it was decided not to attempt to grow any crop to its full yield of grain and straw but to be content with a green fodder crop. On 16-12-22 2½ lbs. of oats were sown in each plot.

Within a week the seeds germinated, approximately equally in all the plots. As there were light showers of rain soon after the seeds germinated, the plots were not irrigated until the first week of January. By this time the seedlings had grown approximately 9 inches high. Plot No. 1 was poor in appearance and plot No. 10 appeared to be the healthiest of all. The other plots were approximately equal in appearance. In the second week of January, Plot

No. 10 was still the best looking, but plots Nos. 7 and 8 began to fill up and to show a mass of dark green colour. In the third week of January, plots Nos. 7 and 8 had outgrown Plot No. 10 and were looking best of all. No. 1 by this time was very poor. In early February, plots Nos. 7 and 8 were so thick that light could no longer reach the roots and the plants became top-heavy with the dew that fell at night. It was clear that in these plots Nos. 7 and 8 half the quantity of seed would have been a more reasonable allowance. Plots Nos. 3, 5, 6, and 10 were growing well. The other plots were growing thin in patches. In the second week of February plot No. 7 had such a heavy growth that it was thought advisable to cut the plot and conclude the experiment, but before a decision was reached a hail storm on 10-2-23 made it necessary to cut immediately. Results are indicated on Table No. 5.

In plot No. 8 only 500 gallons of sludge were taken with the idea that the amount of dry matter put in the plot being only 10 lbs. would probably be insufficient and that the second dressing of 500 gallons which was expected to be required would have a better result if applied to the young plants than if the whole were put at one time. The growth however with the first 500 gallons was so thick that it was decided not to give a second dressing. In plot No. 7, 1,000 gallons of sludge were taken with the intention of bringing the nitrogen content to the same level as in the other plots. As a matter of fact, the amount of nitrogen was in excess of that in the other plot, as the sludge in the plot No. 8 had happened to be weak. It was also originally intended to compare the yield of plot No. 7 where the sludge was applied in one dose with that of plot No. 8 where the sludge was to be given in two doses. In plots Nos. 5 and 10 double the amount of cowdung and consequently double the amount of nitrogen given to plot No. 4 were put with the idea that this would improve the texture of the soil, at the same time as making a large quantity of nourishment available. There is not much difference however in the yields of plot Nos. 4 and 5, though plot No. 10 has shown an appreciably larger yield. Whether this is due to the inoculation of the bacteria from the effluent or from a slight leakeage of sludge it is not possible to say, but it is worth noting that the mere addition of inorganic nitrogen in plots Nos. 2 and 9 did not help the plants as much as the inorganic nitrogen combined with organic manure did in plot No. 3. This is in agreement with the experiment at Rothamsted Farm. Plot No. 6 is very interesting. It was not manured deliberately in any way; but only irrigated with activated sludge effluent. The most probable explanation is that some sludge which may have been sticking to the sides of the main irrigation channel was picked up and carried to the plot by the effluent. Comparing the plots Nos. 7

and 8 and also 6, if the last assumption is true, it appears that the activated sludge is easily available to the plants, and the more it is added (provided the toxic point is not reached) the better the result. This should be borne in mind when the correct proportion of seed for growing green fodder is being considered. It appears probable that if the quanity of seed in plots Nos. 7 and 8 were reduced to half, the individual plants would have thriven better and the ultimate yield would have been as good.

A comparison of the amount of "dry matter" added to the plots 7, 8 and 10 is interesting. In plot No. 7 it is 50 lbs. given in 1,000 gallons of sludge. In plot No. 8 it is only 10 lbs. given in 500 gallons of sludge. (The sludge in the latter plot happened to contain more moisture and therefore less "dry matter" per unit volume.) In plot No. 10 it is 560 lbs. The farm yard manure in plot No. 10 has given a fine yield; but it is less than that of plot No. 8, where there was only one-fourth of the nitrogen and one-fifty-sixth of the weight of dry matter. This fact would become of great importance, if the sludge is ever dried and sold as manure, for the cost of bringing to the site would be comparatively small.

In 1923-24 season, oats were again grown on the experimental plots to compare the yield of green fodder of this year with that of the last year and also to note the yield of grain and straw. The plots of last year had remained fallow after the oats were cut. They were ploughed in early October, levelled and divided so that each plot was 1/40th of an acre in area and the whole area was divided into 2 series each series containing six plots, one being irrigated with tap water and manured with cow-dung and ammonium sulphate as shown in the table 6, and the other series was irrigated with the effluent and manured with sludge as shown in the same table. Out of the 6 plots in a series, 3 were reserved for grain and straw and other three for green fodder.

Activated sludge was taken (as shown in the table 6) in plots Nos. 7, 8, 9 on 9-11-23, and on 10-11-23 in plots Nos. 10, 11 and 12, which were heavily manured. The plots Nos. 7, 8, 9 were purposely under-manured for we found last year that with heavy manuring the growth was very thick and the plants overcrowded each other. The seed rate per acre was also reduced in the sludge plot. It was originally intended to give frequent dressings of sludge to plots Nos. 7, 8, 9 as should be found necessary. Cow-dung and ammonium sulphate were put in the corresponding plots on 10-11-23. The plots were ploughed again and the manure completely incorporated with the soil. The weather was fine and the seeds were sown on 15-11-23 in the proportion of 80 lbs. per acre in water-irrigated plots and 60 lbs. per acre in the sludge plots.

Seeds germinated in a week's time equally in all the plots. Plots were irrigated once a week after this. In the first fortnight plots 2 and 5 looked healthier than the others. But in a month's time the sludge plots began to overtake the others and to look healthier. By 15-1-24 the plots Nos. 11 and 12 were so much overgrown (see photo) that the plants began to fall down and deprive the roots of the light and it was thought advisable to cut them so that the yield of second cutting should not be affected. Plot No. 9 which was to be reserved for grain and straw was also cut partly through a mistake and partly on purpose because the plants in this plot began to fall down owing to stormy winds which occurred at the end of January. It was cut on 28-1-24. By this time the plots Nos. 6 and 7 were also ready for cutting and they were cut on dates shown in the table 6. The yields of the 1st cutting of the various plots are also noted in the table 6. It was found that in heavily sludged irrigated plots the seed rate could be conveniently reduced to 40 lbs. per acre. The plants in plots Nos. 7 and 8 were standing well and a second dressing of sludge was given to them on 15-1-24. The secondary growth after the first cutting was sluggish in heavily sludged plots Nos. 11 and 12 as the roots of some plants were weak, being deprived of light by the heavy growth. The plants in plots Nos. 9 and 10 were good and plot No. 9 was given a second dressing of sludge on 22-2-24. It appears from these experiments that if a maximum yield is wanted in the first cutting, the plot should be heavily irrigated with sludge (80 lbs. N. per acre) and the maximum quantity of seeds (100 lbs. per acre) should be sown. But if two cuttings are to be taken, then the sludge dressings should also be more than one, giving each time a minimum of 40 lbs. N. to 60 lbs. N. per acre for 3 or 2 dressings respectively.

The yields of grain and straw in the various plots are recorded in the table 6. Yield in plot No. 1 was very poor and grain did not mature. In plot No. 3 manured with cowdung and ammonium sulphate the yield of grain and straw is better than in plot No. 2 manured with only cowdung. In plot No. 7 the yield of grain is rather better than in plot No. 3, but the yield of straw is much better. In plot No. 8 the yield of grain and straw is all that could be desired. In "Treatise on Manures by Griffith" the maximum yield recorded by artificial manures in England is as follows:—

Corn ... 60 bushels or 2,112 litres per acre.

Straw ... 4,700 lbs. per acre.

In plot No. 9 the yield is as follows:—

Corn ... 2,120 litres or 1,640 lbs. per acre.

Straw ... 6,080 lbs.

Thus it appears that the Activated Sludge system is remarkably well suited to Indian conditions both as a method of sewage purification and as a means of producing a valuable fertiliser, and by its judicial management on irrigated plots, it is possible to obtain the best yields without causing any appreciable nuisance in the locality and without losing the valuable nitrogen in the sewage.

Plates:

Drawing No.	1	Map of Jamshedpur.
,, ,,	2	Septic Tank.
,, ,,	3	Septic Tank adapted to Activated Sludge Tank (by Jones and Attwood).
,, ,,	4	Activated Sludge tank.
,, ,,	5	General Arrangement of Air pipes.
,, ,,	5A	Details of Special Air fittings.
,, ,,	6	Details of Clifford inlet.
,, ,,	7	Pulsating Gear.
,, ,,	8	Activated Sludge Tank with modifications and blower house, etc.
,, ,,	9	Oat Experiments Plan 1923.
,, ,,	10	,, ,, ,, 1924.

Table No.	I	Sewage Analysis.
,, ,,	II	Effluent Analysis.
,, ,,	III	Sludge Analysis.
,, ,,	IV	Soil Analysis.
,, ,,	V	Oat Experiment 1923 (chart).
,, ,,	VI	,, ,, 1924 (chart).

Photographs—2 Views of the Activated Sludge plant.
,, 2 Views of Oats.

Graphs. I—Chlorine in Sewage and Effluent.
,, II—Average Effluent Analysis throughout one year.

Note: Plates Nos. 1 and 8 and Graphs are reproduced with the paper, the other plates are filed with the Institution.

TABLE No. 1.

SEWAGE ANALYSIS.

Parts per 100,000.

O_2 Abs 3 mts	O_2 Abs 4 hrs	F&S.N	Alb N	Alk	Cl.	Kjeldahl N
...	8.20	1.521	1.520	29.68	3.5	-
.	16.96	1.7704	1.100	29.53	3.7	—
...	1.32	0.378	0.228	16.96	1.8	--
..	...	1.3656	1.750	28.62	3.6	—
...	...	1.2712	0.324	21.56	3.1	0.78
..	11.26	1.6068	0.120	29.26	3.2	3.22
...	11.26	1.8852	1.980	29.68	3.5	9.24
...	13.80	2.0656	2.100	29.26	4.0	0.80
...	1.24	0.800	0.118	—	1.9	2.14
...	14.28	1.8218	1.650	—	3.2	0.52
...	12.18	2.525	1.650	-	3.2	8.40
1.28	12.6	3.158	1.20	30.71	3.4	--
1.28	7.32	2.054	1.68	31.16	3.3	-
2.72	6.80	0.916	0.78	26.50	2.9	—
2.84	12.72	1.108	1.50	28.83	3.0	--
1.32	1.00	0.186	0.485	25.26	2.7	—
2.60	9.70	1.167	1.68	27.14	3.6	—
1.40	6.28	0.791	0.45	21.20	2.2	—
...	8.84	1.110	1.10	27.56	2.9	—
...	8.96	1.230	0.56	22.90	3.2	—

TABLE No. 2.

ANALYSIS OF EFFLUENT.

Parts per 100,000.

Appearance.	Alk.	4 Hrs. O_2 Abs	F&SN	Alb N.	No_2	No_3	Cl.	Kjal-dhal. N
Clear.	—	0.40	0.353	0.081	Nil	Nil	1.3	—
,,	—	0.28	0.585	0.084	f.t.	Nil.	1.4	—
,,	—	—	0.181	0.084	f.t.	f.t.	1.8	—
,,	—	0.50	1,259	0.081	f.t	0.006	2.2	—
,,	—	0.68	0.936	0.075	f.t.	0.07	2.4	—
,,	—	—	0.907	0.075	0.05	f.t.	2.2	—
,,	—	0.60	1,186	0.081	Nil.	0.008	2.3	—
,,	—	0.31	0.756	0.072	f.t.	0.005	1.8	—
,,	—	0.10	1.066	0.090	f.t.	0.004	2.0	—
,,	—	0.68	1.014	0.120	Nil.	0.008	2.6	6.3
,,	—	0.64	1.301	0.105	f.t.	0.006	1.6	2.5
,,	—	0.70	1.140	0.125	0.02	0.007	2.4	2.10
,,	—	0.41	1.368	0.08	f.t.	0.007	2.5	1.82
,,	21.6	0.14	0.85	0.09	f.t.	f.t.	2.0	—
,,	20.78	0.18	0.91	0.09	f.t.	f.t.	2.0	—
,,	22.68	0.64	0.73	0.10	f.t.	f.t.	2.3	—
,,	23.32	0.14	0.87	0.08	f.t.	f.t.	2.1	—
,,	22.26	0.32	0.31	0.04	Trace.	f.t.	2.7	—
,,	22.26	0.62	0.85	0.06	Trace.	f.t.	2.6	—
,,	19.93	0.50	1.03	0.05	Trace.	f.t.	2.3	—
,,	19.08	0.24	0.76	0.05	Trace.	f.t.	2.0	—
,,	17.17	0.18	0.443	0.07	Trace.	f.t.	1.9	—

Average Suspended Solids = 0.1 parts 3 per 100,000.

Dissolved Oxygen taken after 5 days incubation at 37°C.

Experiment 1.	0.8 parts per 100,000.
Experiment 2.	0.8 ,, ,, 100,000.
Experiment 3.	1.3 ,, ,, 100,000.

TABLE No. 3.

ANALYSIS OF SLUDGE.

Moisture per cent.	Mineral per cent.	Organic per cent.	Kjeldahl N per cent	P_2O_5 per cent	K_2O per cent
6.0	21.5	72.5	7.6	-	--
9.08	20.10	70.52	8.88		0.25
			9.13	1.35 (a)	---
6.9	23.2	69.8	7.81	1.66 (a)	-
1.86	23.05	72.08	8.73	1.59 (a)	
1.00	23.21	75.78	8.62		--
1.81	32.63	62.52	6.18		-
1.12	27.62	67.96	7.16		- -
5.91	28.62	65.17	6.61	1.92	
5.11	10.60	54.29	4.91		
6.56	23.77	69.67	7.00	1.81	
3.30	11.02	55.52	5.26		
2.16	29.27	68.57	6.87	2.01	2.2
5.00	23.11	71.56	7.31		--
2.16	29.27	68.57	6.82	2.01	2.21
15.10	23.30	61.3	5.50		
1.50	37.50	58.00	5.60		
1.00	93.10	5.60	-		
0.20	99.20	0.60			
2.21	75.31	22.18	1.12		
8.70	11.51	46.76	3.58	--	-
10.60	32.73	56.67	5.01	—	—
1.80	32.30	62.90	5.29		--
8.95	28.00	63.05	5.10	--	--
0.89	87.63	11.18	0.80	-	-
4.60	32.04	63.36	5.33	-	---

(*a*) Either soluble matter = 5.5%

(*b*) Sludge from aeration tank No. 1 choking the diffusers.

(*c*) Sludge from emptied tank

(*d*) Sludge from Bottom of No. 1 aeration tank when emptied for cleaning.

(1) 2 Litres of Sludge as given to Dairy Farm taken and dried .. . .. = 10·1 Gram. dry matter.
= 0·808 Gram. Nitrogen.

∵ 10,000 gallons of sludge .. = 505 lbs. dry matter.
= 4·04 lbs. Nitrogen.

Our sewage on an average yields sludge .. .. .. = 4·5 per cent. Vol.

∴ 1,000,000 gallons of sewage .. = 45,000 gallons of sludge.
= 2,272 lbs. dry matter.

(2) In an actual experiment with 3 fillings a day from 22,000 c.c. sewage sludge obtained .. .. .. = 5·5 Gram. dry matter.

∴ 1,000,000 gallons sewage .. = 2,500 lbs. dry matter sludge.
= 1·1 tons.

TABLE NO. 4.

ANALYSIS OF SOIL.

OAT EXPERIMENT.

Plot No. 1

After removing coarser particles which formed nearly 10%, the remaining portion was well powdered to pass through linen cloth.

ANALYSIS OF THE POWDER.

Moisture	0·67%
Organic Matter	3·31%
Silica & Insol	84·70%
Fe_2O_3 & Al_2O_3	8·66%
P_2O_5	0·54%
K_2O	0·01%
Undetermined	2·10%
Total.	99·99%

Nitrogen (Kj) 9·09%

The other plots Nos. 2-10 being from the same strata their analysis was not done.

TABLE NO. 5.

EXPERIMENTS WITH OATS, 1923.

Plot No.	Area of each plot.	Seeds per plot.	Manure per plot.	Added Nitrogen per plot. lbs.	Irrigation.	Observation.	Height in Inches.	Yields per plot of green fodder. lbs.	Yields per Acre. lbs.	Yields in units per Acre.
1	1/40 acre.	2¼ lbs. (16-12-22)	No manure.	Nil.	Water.	Growing in thin patches of pale green colour.	14	29 (25-2-1923)*	1,160	1.0
2	Do	2¼ lbs. (16-12-22)	7 lbs. Ammonium sulphate.	1.4	Do	Ditto.	16	62 (25-2-1923)*	2,480	2.1
3	Do	2¼ lbs. (16-12-22)	Cowdung 140 lbs; ammonium sulphate 3½ lbs.	1.4	Do	Growing well in thick patches of both pale & dark green colour.	17	336 (15-2-1923)*	13,440	11.6
4	Do	2¼ lbs. (16-12-22)	Cowdung 280 lbs.	1.4	Do	Growing well like No. 3.	19	194 (14-2-1923)*	7,760	6 7
5	Do	2¼ lbs. (16-12-22)	Cowdung 560 lbs.	2.8	Do	Ditto.	24	222.5 (14-2-1923)*	8,900	7.7
6	Do	2¼ lbs. (16-12-22)	No manure.	Nil.	A. S. Effluent.	Growing well with dark green colour.	21	360.5 (13-2-1923)*	14,420	12.4
7	Do	2¼ lbs. (16-12-22)	Activated sludge 1,000 gals = 50 lbs. dry matter.	3.5	Do	Growing very thick with dark green colour, roots deprived of light.	30	762 (13-2-1923)*	30,480	26.3
8	Do	2¼ lbs. (16-12-22)	Activated sludge 500 gals = 10 lbs. dry matter.	0.7	Do	Growing thickly with dark green colour, roots deprived of light.	31	449 (12-2-1923)*	17,960	15.5
9	Do	2¼ lbs. (16-12-22)	Ammonium sulphate 7 lbs.	1.4	Do	Growing in thin patches.	23	128 (12-2-1923)*	5,120	4,4
10	Do	2¼ lbs. (16-12-22)	Cowdung 560 lbs.	2.8	Do	Growing well with dark green colour.	32	410 (12-2-1923)*	16,400	14.1

* Date of cutting

TABLE NO. 6.

EXPERIMENTS WITH OATS, 1924.

Plot No.	Area of each plot.	Seeds per plot.	Manure per plot	Added Nitrogen in lbs per Plot.	Yield of green fodder 1st. cutting lbs	2nd. cutting lbs	Total lbs	Yield of Grain lbs 18-3-24.	Straw lbs.	Remarks
1	1/40 acre	2 lbs. (15-11-23)	No manure	Nil	.... .	.... .	.. .	8 lbs. 10 litres	24	....
2	Do.	2 lbs. (15-11-23)	Cowdung 560 lbs	4.76	.. ...	. . . .	.. ..	22 lbs. 22 litres	50	....
3	Do.	2 lbs (15-11-23)	Cowdung 280 lbs 3½ lbs. Ammonium sulphate	3 25	....	. ...	... ..	26 lbs. 33 litres	84	....
4	Do.	2 lbs. (15-11-23)	No manure	....	64 (5-2-24)	a47 (20-3-24)	111	......	.....	aGrain forming
5	Do.	2 lbs. (15-11-23)	Cowdung 560 lbs	4 76	281 (5-2-24)	a98 (20-3-24)	378	......	......	aGrain forming
6	Do.	2 lbs. (15-11-23)	Cowdung 280 lbs 3½ lbs Ammonium sulphate.	3 25	246 (31-1-24)	a70 (20-3-24)	316	......	.....	aGrain forming
7	Do.	1½ lbs. (15-11-23)	Sludge 250 gallons (9-11-23) = 5 lbs. dry matter. = 0.21 Nitrogen	0 96	.... ..	. ....	.	30 lbs 39 litres	133	.. ..
8	Do.	1½ lbs. (15-11-23)	Sludge 250 gallons (13-1-1924) = 14 lbs. dry matter. = 0 75 lb Nitrogen. Sludge 500 gallons (9-11-23) = 10 lbs. dry matter.	1 92	......	......	..	41 lbs 53 litres	152 lbs.	... .
9	Do.	1½ lbs. (15-11-23)	Sludge 500 gallons (13-1-24) = 28 lbs. dry matter. Sludge 1,000 gallons (9 11-23) = 20 lbs. dry matter = 0.84 lbs. Nitrogen.	1 42	420 (28-1-24)	178a (19-3-24)	598	. .	.. ...	aGrain & milky juice
10	Do.	1½ lbs. (15-11-23)	Sludge 1,000 gallons. (22-1-24) = 11 lbs. dry matter = 0.58 lb. Nitrogen Sludge 250 gallons (10-11-23) = 17 lbs dry matter.	0 78	320 (25-1-24)	a230 (19-3-24)	550	.	.. ..	aMore milky juice little grain.
11	Do.	1½ lbs. (15-11-23)	Sludge 500 gallons (10-11-23) = 34 lbs dry matter.	1 56	320	a188	508	......	......	aGrain formed.
12	Do.	1½ lbs (15-11-23)	Sludge 1,000 gallons. (10-11-23) = 68 lbs. dry matter.	3 12	385 (16-1-24)	a150 (19-3-24)	535	. .	.....	aGrain formed.

SOME NOTES

OF

CONDENSER TUBES, LOCOMOTIVE TUBES

AND

CUPRO-NICKEL.

BY

ALEXANDER CAMERON, Member.

The history of Solid Drawn Brass and Copper Tube making dates back to somewhere about the year 1838. Previous to this Tubes were made by turning up a strip of metal and brazing the seam—afterwards hammering the Tube approximately round on an iron bar. The introduction of the Locomotive and Tubular Marine Boiler had much to do with creating and fostering a demand for Seamless Tubes.

The first Seamless Copper Tubes were made by casting a cylinder of Copper around an iron core. This cylinder was forged and drawn hot under a power hammer. The shell so formed was turned and bored, then rolled upon a mandril through grooved rolls, and afterwards finished on a draw bench. At a later date a process was introduced for pushing a hole through the centre of solid Copper Billets by means of a powerful hydraulic press. This process is still in use at some factories.

Mannesman invented a process, first applied to Iron and Steel but afterwards applied to Copper, whereby the centre of a cylindrical billet was ruptured by passing it through conoidal rolls, the hole in the centre being afterwards enlarged by forcing the billet over a revolving plug—thus converting the billet into a Tube. Various improvements in this process have been made by others, and to-day these improved rotary piercing machines are producing a large proportion of Copper Tubes—having displaced the hydraulic piercing process in a number of factories.

This paper is confined to the processes in use for making such Tubes of Copper or Brass, and deals with the procedure practised at the Works from which the illustrations have been made. These details do not necessarily represent the practice followed in other factories.

Where Copper Tubes are referred to it may be understood that Arsenical Copper Tubes to British Standard Specifications are meant, and where Brass Tubes are described the alloy will be either two and one quality, or 70 and 30 quality, containing, respectively, $66\frac{2}{3}\%$ Copper with $33\frac{1}{3}\%$ Zinc, or 70% Copper with 30% Zinc. Admiralty alloy for Condenser Tubes containing 70% Copper, 29% Zinc, and 1% Tin, and Naval Brass containing 62% Copper, 37% Zinc, and 1% Tin will be mentioned specifically when they happen to be in reference.

The plant used for the manufacture of Tubes is heavy, bulky, and expensive, requiring very considerable floor space in proportion to the number of workmen employed. The mechanical operations consume much power. The Tube Mill which has furnished the illustrations for this paper is equipped with 112 Electric Motors of an aggregate of 3,570 H.P.

The principal plant items are Chill Moulds for casting, Furnaces for melting and annealing, Pickling Vats, Machinery for piercing billets, Hydraulic Draw Benches, and Chain Draw Benches. The auxiliary machinery consists principally of Circular Metal Cutting Saws, Pointing Machines, Die Polishing Machines, Hydraulic Testing Machines, together with hundreds of Steel Dies and Mandrels of differing diameters and lengths. A Tool Room for making dies, mandrels, guages, etc., and a well equipped Engineering Department are necessary adjuncts for maintaining the supply of loose tools and for dealing with the frequent and heavy repairs which are incidental to this type of machinery.

As illustrating the power required to drive the various types of machines, a hundred ton Hydraulic Bench needs a 225 H.P. Motor to drive the pumps. A set of 3 Benches for finishing Condenser Tubes and geared to draw at the rate of 90 feet per minute requires a hundred H.P. Motor to drive them.

Seamless Brass Tubes may be said to date from Green's patent of 1838. He patented a process for casting Brass Shells in iron chill moulds around a porous sand core. The same process without substantial alterations is in general use at the present day. The method lends itself to casting Shells of any desired weight, thickness, and diameter, such Shells being suitable for drawing on a bench without intermediate forging or rolling.

There was no radical change in the method of drawing for nearly 100 years, except that improvements in benches, giving greater power, stronger dogs, etc., developed as the demand for larger and thicker Tubes grew with the advance in engineering.

Hydraulic Benches were introduced about the year 1900, and have resulted in considerably increasing the speed of drawing, especially of Tubes of the larger sizes.

The Welsh method of refining and casting copper is still the standard method of casting copper shells and billets for tubes, but the introduction of electric melting is a recent departure from the old time method.

The first electric furnace for melting copper in bulk was erected in England in 1920. This method is making such progress in America that many of the largest brass factories have abandoned all other methods of melting.

The selection of the raw materials is an important factor, and an increasing amount of attention is being given by the better tube makers to see that only the highest grades of materials are used. Eleterolytic Copper of 99·9% purity or Best Selected Copper of over 99·75% purity are generally used for the Alloys in Brass Tubes whilst the exclusive use of Zinc of 99·5% and even 99·9% purity is becoming more and more the practice of some makers.

A number of technical terms which are used to denote various processes of manufacture may here be defined :-

Billets are solid cylinders of cast metal.

Shells are hollow cylinders either formed by casting metal around a sand core in a chill mould or by piercing a hole axially through a billet.

Breaking down is the first drawing process in converting a casting or shell into a tube.

Getting down is the intermediate process of drawing preceding the finishing pass.

Swaging or shouldering is the process of reducing the end of a shell or tube to prevent it passing over the mandrel and to enable it to enter the recess in the die.

Pointing is the term used when the end of a tube is swaged for about 6″ and reduced to a diameter which will allow the swaged portion to pass right through the hole in the die.

Coming now to present day methods of production, the manufacture of tubes is divided into two processes, viz., making shells and drawing shells into tubes.

The drawing operations of Brass and Copper are very similar, but the method for producing shells from the two metals differs very

widely. It will, therefore, be necessary to deal with each metal separately.

The fact that Copper can be forged, rolled, and otherwise manipulated hot, whilst Brass is not amenable to hot working, has an important bearing on the difference in the methods of shell production just mentioned.

Dealing with Copper first. The great majority of Copper shells are made by first casting solid cylindrical shaped billets and then piercing holes through them axially.

The Copper is usually melted in reverberatory furnaces having a capacity of from 10 to 20 tons per charge. The charge, consisting of Copper scrap, standard bars, tough ingots, etc., is put into the furnace of an afternoon, melted during the night, refined and brought up to pitch ready for pouring by the time the day gang of workers arrive next morning. It is taken from the furnace in iron ladles, which are thinly coated with fireclay to prevent the Copper sticking to them. It is gently poured into cast iron cylindrical moulds, great care being taken to prevent splashing. The pouring is done by a gang of men who follow each other closely so that there is no break in the operation. The ladles carry about 20 lbs. of metal. The billets vary in weight from 1 cwt. up to 6 cwts. or more.

A variation of the method of hand ladling is to mount a large ladle on a waggon or suspend it on a runway. By these means sufficient Copper can be carried to fill a mould at one operation, except in the case of very large castings.

It may be well to mention that Copper is not tapped out of a furnace into a large receiving ladle in the same way that iron is, because, owing to its high conductivity, it very quickly chills. Where such method has been tried it has been found that the metal frequently freezes in the tap hole, and, moreover, very thick layers freeze to the inside of the ladle. Such layers, or skulls as they are called, are difficult to break up for recharging, because Copper is malleable at all temperatures. It will bend or flatten out, but will not fracture.

The most recent method of melting Copper for making Copper tube billets is by means of the electric furnace. The furnace having a capacity of 2,000 lbs. per charge is of the resistance type, the heat being generated in a resistance ring. This ring consists of a trough or channel of carborundum, filled with granules of carbon. Into the carbon granules are introduced two electrodes one each at opposite sides of the furnace. The carbon granules form a circuit of comparatively high resistance between these electrodes. The passage of

a current through this circuit heats the carbon granules to incandescence. The heat from this incandescent ring is radiated to the concave roof of the furnace and from there down on to the furnace hearth. The temperature of the furnace is regulated by controlling the input of current. As there is no arc there is no area of intense local heating.

Any predetermined temperature within the capacity of the current supply can be obtained and readily maintained within a very few degrees.

It is usual to pour all charges within 10 degrees of the desired temperature. As the input of current is maintained during the pouring process no fall of temperature takes place, and as the metal is poured from the furnace directly into the casting moulds it follows that the casting temperature of every billet is the same.

Billets produced by this process show remarkable similarity in physical and mechanical properties far in advance of anything obtained by other methods. Such physical and mechanical properties are also superior to those obtained by other processes. Defective billets are very rare.

The arrangement for casting the charge when melted consists of a circular revolving table to which are attached sufficient moulds to take the whole of the contents of the furnace. The moulds are hung on trunnions that they may be tilted into a horizontal position for cleaning and dressing and also for withdrawing the billets. The furnace is arranged to tilt around the pouring spout so that the whole of the pouring is done from a fixed point. A 10-horse power motor with a suitable worm gear operates the lifting screw which tilts the furnace. When pouring takes place a mould is first put into position by revolving the turntable. The furnace is tilted until sufficient copper has run out to fill the mould, a thin stream is then allowed to run to feed the billet as it cools. When feeding is complete a partial revolution of the table removes the billet and another one takes its place. The operation is repeated until the furnace is empty. The moulds are hollow cylinders of cast iron. The top ends are dished and the bottom ends are fitted with cast iron discs which have a semi-circular projection in the middle for forming a recess in the end of the billet. These discs are supported in position by carriers hanging from the trunnions. Before the copper is poured the insides of the moulds and the discs are covered with a dressing made of charcoal and oil. This dressing prevents the copper from sticking to the moulds. When cool the billets readily slip out of the moulds after the supports retaining the discs are removed.

The billets after being weighed and inspected are transferred to the piercing department. Here they are gardually heated to a temperature of 900 C in a continuous furnace designed with a sloping bottom and arranged so that the billets charged in at one end will gradually roll down the floor of the furnace during the heating process and be ready for discharging at the other end when fully heated.

There are several methods of piercing copper billets as mentioned in an earlier portion of this paper. It is only proposed to describe one method here. It is an improved Mannesman process and is carried out on a Phillips Gilbert direct electrically driven rotary Piercer.

In design the Piercing Machine consists of two direct driven rolls, whose angles in plan and elevation are so adjusted on the receiving side, as to impart a forward spinning action to the billet until the billet comes in contact with the piercing head. The function of the latter is to pierce and distribute the heated metal in circular section and with equal thickness of walls.

The rotary power is imparted to the rolls direct from two motors of 200 H.P. each, the motors being in synchronism as regards revs., and both are governed and started up from starters which are coupled together to ensure simultaneous starting.

The total weight of the machine is about 45 tons, and the main parts are the bed, two housings, adjustable on bed, for varying diameter of tubes, two main rolls mounted on shafts carried in ball bearings. The two driving motors are mounted on the housings, and drive direct through machine cut gears on to the roll shafts.

A feature of this method of driving is the elimination of loss of power through driving through lines of shafting. Every unit of power consumed is transmitted direct to the rolls for the purpose of piercing.

Another feature of this drive is the absence of any fly wheel, this renders the machine extremely flexible in adjustment for the varying sizes. The range of diameters covered is from 2″ up to 12″. A new machine is in course of erection equipped up to 18″ which is believed to be the largest in the world.

The time taken in the actual piercing of a billet is from 15 to 25 seconds, according to diameter and length.

The adjustment of the rolls for the different diameters is controlled by 8 H.P. motor, reversing, operating through a left hand screw at one end and right hand at the other, connected to the adjustable housings.

The pierced billets, now shells, are quenched in water on leaving the piercer and are then trimmed at the ends, if they are ragged, by means of a circular saw. They are afterwards annealed to remove any internal stresses which may have been set up in the piercing operation, pickled to remove scale and then shouldered under a pneumatic hammer or a knuckle joint pointing machine. They are now ready for the breaking down draw which is given on a hydraulic bench of the push and pull type. All drawing is done cold. Mandrel drawing consists of sliding the shell on to a mandrel then drawing or pushing the mandrel with the tube on it through a die, and afterwards stripping the tube from the mandrel.

The diameter of the die is so related to the diameter of the mandrel, that when the tube is passed through it on the mandrel it not only forces the tube down tightly on to the mandrel, but materially reduces the thickness of the tube wall also.

This displacement of metal lengthens the tube, so the mandrel must be long enough to accommodate the increase.

The bench illustrated has a pushing power of 100 tons with a pull back power of 75 tons when fed with water at 1000 lbs. pressure per square inch. It consists of a hydraulic cylinder 18″ internal diameter by 25′0″ long in which slides a reciprocating piston attached to a 9″ diameter piston rod. The piston rod is attached to a slide at the operating end. The slide and a stay rod together form distance pieces supporting a drawing head. The drawing head is pierced with a hole sufficiently large in diameter to allow the largest tube to pass through that the bench is designed to draw. On the slide nearer to the hydraulic cylinder the head is recessed around the hole to accommodate the drawing die, whilst the opposite side is recessed in a somewhat similar manner to receive a split stripping die. The sliding support of the front end of the piston rod has a mandrel holder, which can revolve in a horizontal plane around a centre pin. This holder is bored to accommodate the shanks of the mandrels, which are all turned to a standard size and slotted to take a standard key. The bench is controlled by a balanced hydraulic reversing valve.

When the bench is in operation a mandrel is fitted to the holder and keyed in. The sliding holder is drawn back as far as necessary. A similar die is fitted to the drawing head.

The mandrel is first swung out of line with the centre of the bench, and a Tube is threaded on to it. It is then swung back into line and locked on a sliding support. The bench is then operated in a forward direction, and the Tube end brought up to the die. The operator being satisfied that the end of the Tube has properly

entered the die, increases the speed of the bench and pushes the Tube right through the die, and through the bench end. The Tube on the mandrel having passed about a foot beyond the outer side of the drawing head, the bench is stopped. A stripping die, consisting of two semi-circular sections which are a sliding fit on the mandrel is dropped into place, and the bench is reversed. As the mandrel is withdrawn from the Tube, the latter falls on the outer side of the bench, on to an inclined plane and is rolled away, leaving the space free for the next Tube to come. This operation has increased the length of the shell by about 35%, reduced the thickness by about 25% and reduced the internal and external diameter. The Tubes are now hard, and must again be annealed and pickled before receiving another draw. If the Tubes are large they will receive the second draw on the hydraulic bench, in which case the shoulder already on the Tube can be used for the second pass.

If the Tubes are comparatively small, say below 2″ internal diameter, they will receive the second draw on a chain bench. The shoulder must be cut away and a new one formed ere this can be done.

Before proceeding to describe drawing on chain benches, the production of Brass Shells will be dealt with. As most Brass Shells are broken down on chain benches, the one description will then suffice for both Copper and Brass.

Brass Shells are made by casting the molten metal around a sand core, in an iron chill. Two types of moulds are used, known respectively as split moulds and cannon moulds. The split moulds are so called because they consist of two semi-circular longitudinal sections held together by cramps when in use. The joints are carefully machined to ensure a good fit, collars are fitted top and bottom to carry the core. The metal is poured down an inclined spout which is cast on to back half of the mould.

Cannon moulds are, as the name implies, hollow cylinders. They are fitted at the bottom with a recessed collar to carry the lower end of the core, the latter being held at the top by a ring fitted with 3 wings to allow the metal to pass round the core during the pouring operation. The inside surfaces of the moulds are dressed with a mixture of oil and charcoal when prepared for casting.

Brass melting for Tubes is almost universally carried out in coke fired pit furnaces using crucibles of various capacities from 120 lbs. to 300 lbs. The casting operation is the most important of all operations in the Brass trade, for on the soundness of the billet depends the quality and suitability of the finished product. Yet it

is the operation which calls most for individual skill and knowledge, and is least amenable to control by mechanical or other non-personal means. It depends almost entirely upon the skill of the caster as to whether sound billets are produced or not. for if the metal is too hot or too cold, or if it is poured too fast or too slowly, defective castings result. The fact that present day pit furnaces are substantially the same as those in use 50 or more years ago is not due to lack of desire on the part of manufacturers to improve them, but because improvement has not been found practicable. The introduction of Tilting Furnaces, and the advent of Electric Melting Furnaces has greatly improved the procedure of casting slabs, strips and billets, but successful achievement has yet to be recorded in the manipulation of the latter Furnaces so that the delicate operation of Brass Shell Casting can be said to be possible by their aid.

The procedure for casting Brass Shells is as follows :--

The various components of the alloy are weighed out in suitable quantities and loaded into iron pans. Each pan contains a charge for one crucible. The copper is first put into the crucible, and melted under charcoal. A handful of salt is thrown in to flux the copper oxide. Any Scrap that may form part of the charge is next added, and when this is thoroughly melted and stirred in the zinc is added also. As the zinc has a lower specific gravity than copper, it tends to float on the top of the charge. Constant stirring must therefore be maintained to prevent undue losses by evaporation of zinc, and also to ensure a homogeneous mixture. The addition of the zinc causes a considerable reduction in the temperature of the charge. The metal must therefore be allowed to remain in the furnace a short period to raise the temperature to pouring heat.

Immediately the castings are solid they are withdrawn. Owing to the formation of a thin layer of carbon between the face of the casting and the mould, the casting can be readily lifted out. Immediately it comes in contact with the air the layer of carbon burns off, leaving the surface perfectly clean. The castings are allowed to cool, and then the core bars are knocked out and the sand removed with a scraper and a wire brush.

The castings are now known as Brass Shells. They should be smooth and clean inside and outside, and ready for breaking down after a preliminary annealing and pickling. This preliminary annealing is not carried out in all factories. The author considers it an important operation, as it normalises the crystal structure of the metal before mechanical work is put upon it.

It is the practice in the case of Shells for Condenser Tubes for the British Admiralty to bore and turn them before the first drawing operation. This practice is also being adopted to an increasing extent by the Advisory Engineers of the large Steamship Companies and some of the Engineers of land power plants for their Condenser Tubes. The longer life and greater freedom from corrosion of the resulting Tubes being considered to be well worth the small extra cost entailed. A large number of Railway Companies also have the Shells for making their Locomotive Tubes bored before the first drawing operation is put upon them.

Brass Shells are generally broken down on chain benches. From this point the operation of drawing Brass Tubes is similar to that for Copper Tubes which have left the hydraulic benches.

A chain bench consists of a shallow channel-shaped bed with a broad track on either side, usually made of cast-iron, and supported on cast-iron legs. At the driving end of the bench a sprocket wheel is fitted, over which an endless chain passes. This sprocket wheel is connected with suitable gearing for driving. At the other end of the bench is a drum to carry the chain. It runs in bearings which are carried on slides at either side of the bench and which can be adjusted by tension screws to keep the chain at a proper tension. At the end of the bench, opposite to the pulling gear, brackets are fitted to support the die. The chain runs in the channel of the bench, and a pulling dog runs over the chain, supported on four wheels which run on the track on either side of the chain. One end of the dog is fitted with pliers to grasp the end of the mandrel, the other end is fitted with teeth to engage in the chain. These teeth are fixed in a counterbalanced hinged arm which lifts in a vertical direction, so that the teeth are automatically lifted clear of the chain when disengaged.

The mandrel for use on a chain bench is a round bar of steel reduced in diameter at both ends. The ends are slotted or headed for the purpose of engaging with the pliers of the drawing dog. A small turntable is placed on the floor immediately in front of the draw bench, to support the mandrel when the Tube is being threaded on to it, and to swing it round when reversing for the withdrawing operation.

The die is a circular or hexagonal piece of steel pierced with a round hole. The hole is recessed conically to act as a lead for the Tube. The pulling off die is usually of brass. The hole in the latter is not recessed. This die must be a good sliding fit on to the mandrel to prevent the possibility of the Tube being drawn into it and bursting it, instead of stripping from the bar.

The operation on a chain bench differs from that on a hydraulic bench, because the chain bench is not reversible.

The Tube is first shouldered. It is then threaded over the mandrel bar. The shouldering must be such as to allow for the leading end of the mandrel to pass freely through the reduced portion of the Tube, but the reduction must be sufficient to tightly engage with the shoulder of the mandrel, otherwise the mandrel will be drawn through the Tube when the drawing operation begins. When the Tube is threaded on to the mandrel, the leading end of the latter is passed through the die, and is secured to the drawing dog. The teeth of the drawing dog are then allowed to engage with the draw chain which is constantly travelling along the bench. The tube is thus drawn on to the mandrel.

As the teeth of the drawing dog are held in the chain by tension the dog is released immediately the tube is through the die, owing to the tension being relaxed. The bench operator displaces the drawing die, immediately pulls back the mandrel with the tube on it on to the turntable in front of the bench, swings the mandrel round, puts in position the stripping die, and pushes the reverse end of the mandrel through the same. Meanwhile, the dog has been returned to the front end of the bench. The reverse end of the mandrel is now secured into the dog and the teeth of the latter engaged with the bench chain. The mandrel is thus drawn out of the tube, completing the cycle of operations.

After being drawn the tube is again annealed and pickled.

Annealing is carried out in closed type furnaces so designed that the products of combustion cannot come in contact with the metal which is being heated.

Whilst this type of furnace involves greater fuel consumption than open or inflame furnaces, the extra cost is offset by the improvement in the quality of the material treated. It is possible to maintain a far more even temperature. There is no possibility of local overheating or burning due to contact with flame. Oxidation and scaling is reduced to a minimum, and as regards Brass, red staining due to furnace gases is eliminated.

When *annealed the tubes are withdrawn on to waggons* and allowed to cool, if of Brass, but tubes of Copper are quenched in water immediately on withdrawal from the furnace. When cold *they are placed in a bath of dilute sulphuric acid, and allowed to* remain there until all scale has been dissolved from the surface. This occupies from 5 to 15 minutes. They are then plunged into a tank of clean water to remove the acid, withdrawn and allowed to dry.

The tubes are now ready for a further cold drawing operation.

The operation of drawing, annealing, pickling are repeated several times until a tube of the desired length, diameter, and thickness is obtained.

The shoulder or collar can generally be used for two successive drawing operations. It is then cut away and a new shoulder formed.

When finished tubes have been cut to length they are straightened and then subjected to an internal hydraulic test of a pressure commensurate with the thickness and diameter of the tube, but always four or more times the working pressure for which the tube is suitable.

An alternative method to mandrel drawing is the process known as plug drawing. In this process the mandrel is not drawn through the die with the tube upon it, but the tube is drawn over the mandrel when being pulled through the die. Instead of the long bar previously described the mandrel for plug drawing is a short piece of round steel—termed a plug—of the internal diameter of the tube. It is screwed on or otherwise attached to a bar of a smaller diameter of a length of 15 or 20 feet.

To the ordinary drawing bench an extension piece is attached approximating to the length of the bench itself. At the end of the extension piece farthest from the die a pair of brackets and a plate somewhat similar to the die plate are provided.

Through a slot or a hole in this plate is passed the end of the bar carrying the plug. It is prevented from being drawn forward by a washer, and an adjustable nut to accommodate the latter is screwed for a length of six inches or more.

The overall length of the bar and plug must be such that when in position and properly adjusted the plug just enters the die on the drawbench. The slot or hole in the back plate must be such that the bar can readily slide backward through it.

The operation of plug drawing consists of first swaging down the end of the tube for a length of about six inches to a diameter that will freely pass through the die. The tube is then threaded over the plug and along the bar. To facilitate this the plugging bar is pushed backward a short distance through the back plate. After the tube is pushed home over the plug the swaged end is passed through the die until the shoulder engages with it.

The bench dog is provided with suitable pliers, which, seizing the swaged end of the tube, draw it over the plug and through the die. When the tube has passed completely through the die the dog is automatically released from the chain, the tube rolls off the bench and the dog is drawn back to the front end of the bench by an automatic return device.

By this method of drawing there is no time lost in stripping the tube from the mandrel, consequently quicker passes can be made. The tagged end increases the amount of scrap.

The process is chiefly used for thin and small sizes and for tubes which must be parallel inside.

Another method of drawing is known as hollow sinking. This process consists in merely drawing a tube through a die, without using a mandrel or plug to reduce the thickness.

By this operation the tube is made longer and smaller in diameter but the thickness is increased. It is only applicable to copper tubes as brass tubes drawn in this manner are rendered liable to season cracking.

This method is used chiefly for the production of long copper tubes for heating coils or for refrigerator. The latter require very long lengths, 50 feet each is quite a frequent demand, whilst tubes of 80 feet are at times requisitioned.

The tubes which are to day receiving most attention from Metallurgists and Engineers are solid drawn tubes for surface condensers for Marine Engines Electrical Power Stations and the like.

For many years the British Admiralty have issued a specification governing the manufacture of condenser tubes for the Navy. From time to time this specification has been modified until it is now by far the strictest specification issued to govern the manufacture of any tubes. The necessity for meeting this specification has resulted in the perfecting of devices for producing shells free from blow holes and other defects, the introduction of machines for boring and turning the shells before they are drawn, special furnaces for annealing, improvements in the quality of steel used for dies and mandrels, and particularly in the means adopted for preventing dies or mandrels marking the tubes on the inside or outside. What the author believes to be the first large closed type annealing furnace used in the non-ferrous tube trade was introduced for the purpose of improving the quality and finish of Admiralty condenser tubes, and the first ground and polished mandrels were used for the same purpose. Reamers for removing the sharp edges and burrs on the ends of tubes after cutting and before

further drawing and devices for drying, cleaning and sighting internally, have all been developed as the result of the efforts which have been concentrated on making these tubes as near perfect as humanly possible.

The Admiralty specification demands that the following tests shall be applied by their Inspectors to every condenser tube before acceptance :—

Testing to 1,000lbs. per square inch by hydraulic pressure, the tubes being jarred or hammered with mallets whilst the pressure is maintained. Tried with gauges to prove the external and internal diameters, the thickness, and the concentricity. Hammered on the ends with a mallet whilst held loosely in the hand. Dropped on a hard wooden floor. Flattened at either end to 5/16" diameter without cracking. In connection with this test, the tube must yet be hard enough to stand screwing up tightly with taper grumets in the glands of the condenser without collapsing. After the tubes are so screwed up a gauge is inserted in each end to test for collapse.

Examined on the outside for surface defects. Sighted for internal defects whilst lying on a suitable table, and with the aid of electric light so arranged that parallel rays can pass through the tube.

Tubes which successfully pass all these tests are grouped in parcels of a hundred.

Two from each hundred are selected at random, and the ends are heated to redness. If one tube splits the whole hundred are rejected.

If the two tubes pass this test they are then cut open and examined internally. If one shows internal defects, two others are taken and tested in like manner. Should one of these latter fail then the parcel is rejected.

Rejection of 20 per cent. of the parcels entails the rejection of the whole quantity under survey.

In connection with the sighting test, tubes set aside are kept apart from other rejects and 20 per cent. are cut open to examine the nature of the defects which have caused them to be thrown out.

Tests such as these, rigidly enforced, necessitate the greatest accuracy and care in manufacture, otherwise the rejections are ruinous.

The various tests as they have been added to the specification from time to time have brought forth the various improvements in

process necessary to meet them. The flattening test caused the introduction of the closed furnace as only perfect regularity in annealing will give the test with certainty.

The sighting test necessitated improvements in mandrels both in perfection of surface and accuracy of diameter. The author can remember when a turned mandrel, lapped and polished would only draw 500 to 1,000 tubes before being worn out. To-day it is not unusual for a mandrel to draw 10,000 tubes before being discarded, and be it remembered, its life is limited to wearing down 5/1,000 of an inch from the original diameter.

A mandrel for making Admiralty tubes is something of an engineering achievement. A full length bar has a working length of 20 feet, a diameter of ·525 inch at one end, with a gradual taper to ·529 at the other end. It must be perfectly round and straight, free from the slightest kink, with a surface like a mirror and a skin that is glass hard, yet it must be flexible and very tough, otherwise it would quickly snap.

Although grinding has been a recognised method of preparing bars of accurate diameter for many years, it is only of recent date that a machine has been perfected that can grind small diameter bars 20 feet long sufficiently accurate to meet the requirements of such a tube mandrel, and even to-day there is no machine which will grind and finish a bar good enough. The final tapering has to be done by hand, and by buffing on a polishing machine.

It is all to the good, that many of the improvements in manufacturing practice, originally applied to Admiralty condenser tubes, have gradually been added to the means for producing the ordinary commercial tubes. Casting improvements and improved annealing furnaces are features which may be specially referred to. As previously mentioned, all classes of tubes now have their annealing temperatures checked and regulated by the aid of recording pyrometers. It is no longer a matter depending on the judgment of the annealer as to whether the tubes are hot enough or whether they have been maintained at a particular temperature for a sufficient time. The pyrometer answers all these questions accurately and unfailingly. The sighting table has revealed the possibility of intenal defects being caused by small bits of brass dust and other extraneous matter getting into the tubes. The use of reamers for removing burrs, brushing out devices, etc., has developed as a consequence. Only a decade ago a sighting table was something of a curiosity found only in the examination rooms; to-day sighting devices are placed in various convenient positions in the Mills, and are used to examine the inside surfaces of tubes at all stages of manufacture.

About a year ago my Company was entrusted with the work of re-tubing the condensers of the T/S.S. "City of Poona." All the tubes apparently gave out suddenly on a voyage from London to Calcutta, after being cleaned by some process or another.

The corrosion of condenser tubes has been studied in detail for some years and extended investigations have been made by the Corrosion Research Committee of the Institute of Metals. Primarily it is a chemical problem and therefore concerns the chemists and metallurgists rather than the Engineer.

It is difficult for the Engineer, who is directly engaged in industry, to keep in touch with the advances that are being made by the metallurgist to-day. Until recently the importance of the subject was not sufficiently recognized. To-day the progressive development of the metal industry compels attention. There is an ever-growing appreciation of the great advantages offered by the use of non-ferrous alloys containing nickel and copper and the demand grows more and more each year.

Nickel has a decolorising power greater than any base metal in common use, and produces bright silver like alloys from metals such as copper and brass. One part of nickel will completely decolorise three parts of copper. The *Nickel Addition* increases the strength and the resistance to corrosion.

It has been found that one of the chief factors in accelerating the corrosion of condenser tubes is the high vacua and higher water speeds particular in turbine plants. Another cause is the impure river waters and salt water used ashore and afloat. Cupro Nickel condenser tubes have given results which are not to be obtained with any other alloy.

Cupro Nickel is a comparatively new alloy in the non-ferrous group, and is one of the most interesting and valuable alloys of nickel which has been successfully used in the form of tubes for condenser tubes, locomotive tubes and for other purposes where a metal resistive to corrosive attack is desired.

Cupro Nickel is an alloy entirely free from zinc and is the least corrosive commercial alloy for Condenser Tubes. It is the best possible material that can be used where very bad working conditions have to be met.

Two or three years ago brass, in its various compositions, was practically the only material for condenser tubes on account of its durability, heat conductivity and cheapness. To-day brass is being substituted by Cupro Nickel.

Cupro Nickel has been manufactured in the form of sheet metal for a number of years, but it is only since the termination of the war that means have been found for successfully manufacturing the metal into tubes. It resembles Nickel in appearance, takes a high polish, and it is not easy to distinguish it from Nickel by casual observation.

The growing demand for Cupro Nickel is chiefly because of its natural strength and hardness and its high resistance to the action of temperatures above the normal such as superheated steam and to corrosion.

There are various grades of the alloy, the principal ones being as follows :—

98% Copper, 2% Nickel and 90% Copper and 10% Nickel, (both of which are used for making locomotive boiler stays). For locomotive tubes the alloys 98/2 and 95/5 are in general use. For condenser tubes alloys of 95/5, 90/10, 85/15 and 80/20 are made.

In the U. S. Navy they use 60/40 for condenser tubes and for feed water heater tubes the nickel content is 15%.

Cupro Nickel alloys are not subject to corrosion or season cracking as are the brasses and bronzes. Nickel has a protective effect upon copper in proportion directly varying with the amount of nickel in the alloy, but it also has the effect of increasing the difficulty of manipulating, broadly speaking, in the same proportion.

As a consequence the alloys available for one purpose may not be available for another purpose, owing to the difficulties of manufacture. This difficulty of manufacture obviously increases the cost of production, so that alloys of a higher content of nickel cost considerably more than those with the lower content, the difference being much greater than would be indicated by the price of the raw material.

In dealing with the application of these alloys, the stay bars made of 98/2 alloy have a higher tensile strength than ordinary copper with an equal ductility and a greater resistance to the attack of corrosive water in the boiler. The 90/10 quality stays have a *much greater resistive power* to corrosive water, their tensile strength is much higher, and yet the ductility remains at a high factor. Stays made with this material can be bent double cold, after screwing. This is a test which can only be made with great difficulty even by soft copper rods. The heads of stays made of this metal do not burn off inside the firebox.

One of the characteristics of this metal (90/10) is its high tensils strength at temperatures above the normal. This is illustrated in the test sheet herewith. Particular attention is drawn to the elastic limit at high temperature. Take, for instance, the temperature at 300 c. which is equivalent to boiling point of water at about 200lbs. pressure per square inch (the highest pressure used by locomotives). It will be observed that at this temperature the elastic limit of copper stays falls by 50% whilst the elastic limit of Cupro Nickel falls only 6 or 7%. Furthermore, the actual elastic limit in tons per square inch is many times higher than copper.

Boiler tubes of 98/2 Cupro Nickel have been in use for 25 to 30 years on many railways. They have shown great advantage over copper and brass in areas where bad water conditions cause pitting and corrosion to the latter metals. There are areas out in South America where this metal is giving satisfaction under conditions where neither steel, brass or copper can be successfully used owing to the saline qualities of the water. The 95/5 quality of Cupro Nickel boiler tubes are being used in areas where conditions are extremely bad, the increased content of nickel proving serviceable in rendering the tubes yet more resistive than the 98/2 quality.

I would point out that Cupro Nickel, particularly 80/20 quality, is a highly ornamental metal and can be used for such purposes as curtain rods, towel rails, ships' hand rails and hand rails in power stations and ships generally. It is a silver white metal, very slow to tarnish, and is being used in quite a number of cases in connection with nickel-silver fittings for bathrooms, lavatories, etc.

In conclusion, I wish to acknowledge with thanks the assistance I have received from Mr. G. H. Whiteman and Mr. A. Spittle in the preparation of this paper and Messrs. Allen Everitts for the courtesy extended in allowing me to go over their Works.

HIGH TEMPERATURE TENSILE TESTS ON COPPER AND CUPRO-NICKEL

(90% cu. 10% NI).

$1\frac{1}{8}''$ dia. × 2′–0″ LENGTHS. YIELDS TAKEN OVER $16\frac{1}{2}''$ GAUGE LENGTH.

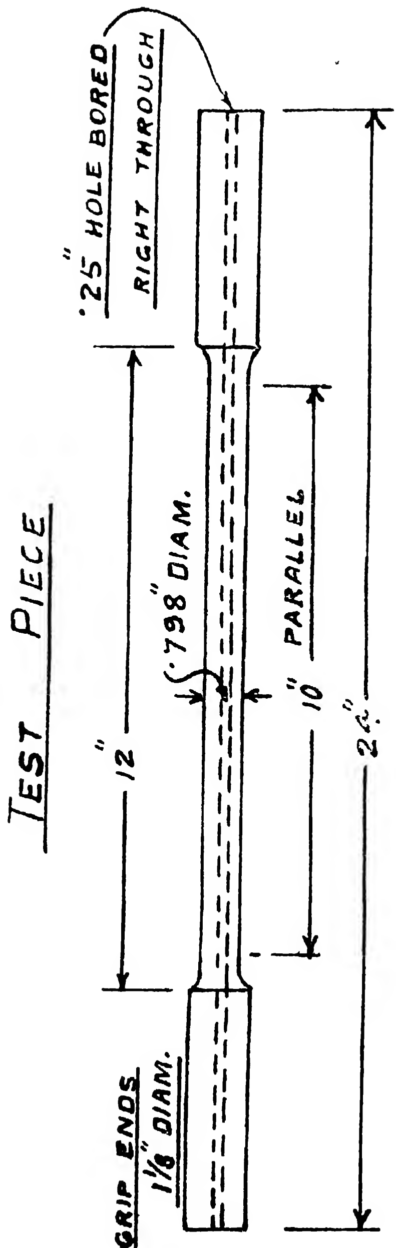
Material.	Temp.	Area per sq. inch.	Yield Actual Tons.	Ult. Actual Tons	Yield Stress Tons.	Ult. Stress sq. inch.	% Elongation. On 1 in	On 2 in	On 6 in.	Reduction of Area Area.	R A %	Remarks.
Cu-Ni	Room	.4448	7 5	10 22	16 87	23 0	58	35	14 3	1527	65.7	Cupped, silky fracture.
Cu	Room	.4448	1 68	6 30	3 78	14 16	67	55	42 6	2105	52.7	.. .. ..
Cu-Ni	153°C	.4498	7.5 at 160°C	9 41	16 7	20.92	40	21	7 7	.1257	72	. .. .
Cu	150°C	.451	1 17	5 38	2 59	11 93	72	60	42.7	1814	59 8	Silky fracture.
Cu-Ni	300°C	4524	7 0	8 69	15 48	19.21	38	23	7 7	1357	70	Cupped, silky fracture, discoloured
Cu	300°C perhaps lower	451	1 0	4 4	2 22	9 76	64	58	39 7	.1945	56.9	Slight scale, cupped, silky, fibrous fracture.
Cu-Ni .. .	400°C	4349	2.78	6 48	6 4	14 9	44	24 5	8 7	1521	65	Clear, silky fracture, slight scale, local reduction.
Cu	400°C 390° min.	451	1 05	2 66	2 33	5 90	28	23	15 7	3812	15 3	Piece broke out of centre Thin scale over length of specimen.
Cu-Ni ..	500°C	451	3.4	5 28	7 54	11 7	45	29	11 7	2601	42.4	Rather coarse fracture, clear scaled, mottled appearance under scale
Cu ..	500°C min.	4498	1 14	2 20	2 54	4 89	14	11 5	8 3	3954	12.3	No local reduction, scaled badly, very coarse fracture

CITY OF BIRMINGHAM GAS DEPARTMENT, INDUSTRIAL RESEARCH LABORATORIES, COUNCIL HOUSE, BIRMINGHAM. 6/12/22

SPECIAL TENSILE TESTS—The objects of the tests were to determine the tensile strengths and relative data of Copper and Cupro-Nickel Bars. Special test pieces were prepared to the dimensions shown in sketch. The central hole was for the purpose of inserting an electric thermo-couple for measuring the temperature of the test specimen. The test specimens were supported vertically, in a 25-ton Avery Tensile Machine, being enclosed in an electrically-heated tubular furnace. The specimen was brought up slowly to required temperature, and kept at that temperature for about half an hour prior to actual pulling. Temperatures were also taken during the pulling of the specimen, and it was found that a small drop occurred during that period.

C. M. WALTER, *Engineer-in-Charge.*

CAMERON on CONDENSER & LOCOMOTIVE TUBES.



NOTE ON THE RIVERS OF BENGAL

BY

C. ADDAMS WILLIAMS (Member).

PRINCIPAL RIVERS.

The Province of Bengal as now constituted is supplied for the most part with water derived from sources without its boundaries. The three principal rivers are the Ganges, Brahmaputra and Meghna, all of which enter the Bay of Bengal through a common estuary at the eastern end of the dèlta and known as the Meghna estuary: the supply in these rivers is supplemented by water brought down by smaller rivers from the Himalayas on the north or the Chota Nagpore hills on the west: of the total volume of water supplied by the river system as a whole, only a fraction passes to the sea through the spill channels which traverse the delta, such as the Hooghly, Jaboona, Gorai and Urial Khan: in the eastern portion of the delta beyond Khulna a large amount of water, however, spills freely over the land and is to a large extent discharged into the sea by an entirely different group of rivers to those from which spill takes place: these rivers have their origin at the southern fringe of the bhil area in the latitude of Calcutta.

COMPOSITION OF THE DELTA.

The delta of the Ganges and Brahmaputra commences at Rajmahal and extends to the eastern boundary of the Province. The rivers never attain regime. Vast quantities of finely divided material are transported by them every year in the flood season of which a large portion is utilised in delta building in inland tracts. North of the latitude of Calcutta the soil will be found to be comprised of a very fine grey micacious sand with a small proportion of silt, but in the tidal area the character of the soil changes to a stiff blue clay. These deposits overlie deposits of an older age which comprise layers of yellow clay and sand. The outcrop will be found along the edge of the present delta and the strata dip down under the more recent deposits: along the Hooghly they will be found at a depth of 60 to 100 feet below the surface: north of the Ganges they appear on the surface in the Rajshahi Division and on the east are marked by the Madhupore jungle: there also appears to be an outlier at Kushtia. The clay strata are particularly hard and compact: the sand is very coarse and full of sweet water. It would appear therefore that an old delta must have existed at some time in the

past which has been depressed and that the present delta has been laid down on top of it. The newer strata, except in the tidal area, are devoid of compactness and the finer particles are easily transported by the wind. It can therefore be easily understood that rivers traversing such soil frequently change their courses due to erosion or concentrated spill.

MAJOR CHANGES IN THE RIVER SYSTEM : GANGES.

A few of the major changes in the river system may be mentioned. It is well known that the Ganges used to flow for the most part along the western and central portions of the delta through the Bhagirathi and Bhairab and their offshoots: at some time not definitely ascertained this river forsook its old course for a south-easterly one, and now passes to the sea *viâ* Goalundo: there is nothing on record to show that this change was the outcome of anything except normal deltaic action. Deltaic rivers not only extend their deltas towards the sea but also inland: due to the lengthening of their courses they have to rise to a higher level at the heads of the deltas in order to generate sufficient fall to counterbalance the additional length. The level of the water must therefore rise at the point of entry to the delta, thus creating a fresh water spill which raises the land by silt deposits: as the levels rise as time goes on the area subject to fresh water spill must necessarily extend more and more inland from the original head of the delta and a heaping up of the deposits must take place until the time arrives when the river breaks through into lower ground along the margin of the delta. When water from a river is released by a comparatively sudden avulsion the level is reduced, with the result that the older channels are deprived of water and in consequence deteriorate: at the present day the main course of the Ganges runs along the northern fringe of the delta in full vigour whereas the Bhagirathi has deteriorated considerably and the Bhairab is extinct for the greater portion of its course.

EFFECT OF THIS CHANGE ON THE SPILL RIVERS : BHAGIRATHI.

Now let us trace the effects of this major change a little further: the Bhagirathi in the days of its activity poured its waters into the Bay of Bengal through several mouths. At Nowserai (Tribenighat) the river divided into three streams: the Saraswati on the west, which can still be traced through the Hooghly and Howrah districts, to the point at which it enters the Hooghly at Sankrail at the western end of Garden Reach: this branch is believed to have sent .. offshoot ' 'he direction of Ampta but the exact course is not ¯oghly, or central branch, which after reach- ◦ sea through the Adi Ganga or Tolly's

Nala: the course of this old river can still be traced to Garia, Baruipore and Jaynagar; and the Jaboona, or eastern branch, which after passing in a more or less easterly direction to Tibbi, turned southwards through the central Sunderbans to the sea: this branch of the river undoubtedly was responsible for the formation of the Matla estuary because it threw off a branch close to Basirhat, known as the Bidyadhari, which after a circuitous course enters the Matla at Port Canning.

BHAIRAB.

In the case of the Bhairab, the head reaches are still active from the offtake from the Ganges to where the river joins the Jalangi: below this junction the river, with the exception of a few miles near Khulna, is dead, together with its offshoots the Kodla, Betna, Kobadak, Bhudder, Harihar and Mukteswari: to the north of the Bhairab there are other dead rivers which were probably dependant on the Bhairab for their supply, such as the Chitra and Nabaganga.

The Bhairab which means "The Terrible," was a larger river than the Bhagirathi. The former with its spill channels distributed its water over a much larger area of the delta, and there appears therefore to be little doubt that the Bhairab was the more important of the two.

TISTA.

Turning to the case of the Tista river: in 1770 this river, which issues from the Himalayas close to Siliguri, is shown as passing due south through the Jalpaiguri, Dinajpur and Rajshahi districts more or less along the present course of the Atrai: it is, however, known that this river previously traversed the country south of the hills in a south-easterly direction on much the same course it now follows: whether the Tista followed the Atrai course before the Ganges broke through to Goalundo or not is not known: if so, it is not clear in what direction it flowed to the sea: it may have skirted the northern fringe of the Gangetic delta. In any case, for a considerable period prior to 1770 it must have discharged its waters into the Jamuna to the south of Serajgange, passing over the country now occupied by the Chalan bhil.

Owing to a very large flood the river burst the left bank a few miles above Jalpaiguri in 1787, due it is said to the enormous volume of sand carried down by the flood which choked the bed of the river. As a result of this irruption the Tista reverted to its old bed and resumed its flow into the Brahmaputra. At the present day it continues to follow this course tapping many of the rivers emanating from the hills on its northern bank: enquiries show, however, that no overflow now takes place over the right bank. All rivers lying

between the Tista and the Ganges now discharge no water from the hills and are deteriorating in consequence.

BRAHMAPUTRA.

The next major change was that of the Brahmaputra, when this river left its Mymensingh course and breaking through the Jenai, joined the Ganges at Goalundo. This change was probably the out come of the diversion of the Tista. The flood water of the latter river, as already stated, used to discharge into the Jamuna at Bera : at this time there was a connexion between the Jamuna and the Bramaputra through the Jenai : as a result of the diversion of the Tista the quantity of water entering the Jamuna was decreased and more water was poured into the Brahmaputra, so that the slope through the Jenai must have been steepened with the result that the Brahmaputra took the least line of resistance and the shortest course to the sea : this change appears to have begun about the end of the 18th century and to have been a comparatively slow one at first : there is, however, evidence to show that the waters of the Ganges were dammed back by those of the Brahmaputra between 1818 and 1833, with the result that the Ganges threatened to change course down the Gorai and Madhumati. The latter river came into existenece at this time; in 1818 it was a small khal, called the Elankhali Khal, whereas in 1833 it was 800 yards wide.

KIRTINASA.

Shortly after these changes the combined waters of the Ganges and Brahmaputra broke through the narrow neck of land separating them from the Meghna : prior to this the Ganges flowed into the Bay of Bengal near the mouth of the Meghna passing close to Madaripur and Gournadi : the change in the course of the Brahmaputra must have decreased the supply of water in the Meghna and increased that of the Ganges so that the difference in levels across the neck must have increased. A small khal, called the Kirtinasa, appears to have afforded a means of passage and the river broke through and joined the Meghna near Chandpore, forsaking the Madaripur bed, which is now fed by a few small spill channels. It is stated that the connecting link between the old and new courses was three to four miles wide in 1840 : there is a record to show that in 1838 the Ganges was fordable above Goalundo, which is put down to the increase in the volume of water passing down the Gorai. The pressure at this point appears, however, to have been relieved by the irruption which opened the Kirtinasa connexion.

MYNACOTTA 1924.

The rapidity with which these deltaic rivers can change their courses will be grasped by the following example which took place

last year: the Mynacotta and Urial Khan rivers between the Padma and Madaripur, which flow to a large extent through the land formed after the Ganges left the Madaripur course, completely changed their courses: the offtake of the Mynacotta from the Padma is seldom at the same spot for two years in succession, but the central and lower reaches have been comparatively steady for some time up to last year. The river in 1922 was comparatively straight below Berhamgange: in 1923 the Sarsa Khal began to open: in 1924 this khal became the main river cutting off a large loop of the Urial Khan: probably in sympathy with this shortening of the length the river has formed into a series of long S curves above the khal, and in all, about 25 miles have so completely changed course that it is hardly possible to recognise the older channel.

EFFECT OF THESE CHANGES.

The effect of all these changes has been that the river system at the present day is totally different to that of even 1½ centuries ago. The old delta builders which used to flow in a southerly or south easterly direction have for the most part been severed from the parent stream and there are in consequence large tracts of country which are cut off from a fresh water supply.

NEW RIVERS.

One of the results of these changes has been that new rivers have formed: the Jalangi opened about 100 years ago: originally it had a common head with the Matabhanga and flowing to the south-west crossed the Bhairab almost at a right angle, carrying a supply of water from the Ganges to the Bhagirathi at Nadia: in recent years the head has closed due to encroachment by the Ganges which caused the Matabhanga to open an independent intake. The central and lower reaches of the Jalangi are now fed through the upper reaches of the Bhairab, which reopened when the supply from the upper Jalangi was cut off.

Portions of the Matabhanga are also new and are believed to have formed only 100 years ago. This river bifurcates into two, one stream passing by the Churni into the Hooghly and the other supplying the Ichamati and lower Jaboona with water. The case of the Madhumati has already been cited: an offshoot of this river to the north east of Khulna has opened in comparatively recent times and is called the Attarabanka or eighteen bends. The case of the Dhaleswari in the Mymensingh District is different: this river was a spill channel of the Ganges and some think was the main Ganges itself at one time: the Brahmaputra cut across this river and has appropriated it as one of its spill channels: the head of the Dhaleswari has in consequence moved many miles to the north

and the intake at the present day is opposite Serajgange near Porabari.

DAMODAR.

The only other major change which need be mentioned is that of the Damodar which rises in the Chota Nagpur hills. This river probably at one time discharged directly into the Bay of Bengal at some point above Calcutta and also probably contributed to the formation of the old delta: when the Ganges filled in the Bay in this vicinity, the Damodar began to throw down an independent interior delta of its own, the apex of which is now situated about 20 miles to the west of the town of Burdwan; but it is quite clear from an examination of the subsoil that the apex has not been for many years in its present position, because the depth of new alluvium is only 6 or 7 feet: the apex has been forced at an abnormal rate further upstream by the hand of man by the erection of embankments. The left bank is now strongly held and the river is forced to continue its delta building functions along the right bank only, where the embankments were removed some 65 years ago: about the year 1770 the Damodar burst its right bank near Selimabad and following the Gushkara khal opened a mouth into the Hooghly at Falta, and it is practically certain that the head of the delta was close to Selimabad at that time. This change caused the deterioration of the Kana Nadi, the principal channel connecting the Damodar with the Hooghly. The head was finally closed at Selimabad by the continuation of the embankment across it in 1866. There was also a spill channel of the Damodar called the Kana Damodar which left the parent stream close to the head of the Kana Nadi and entered the Hooghly near Uluberia. It is probable that this river also expired as a result of the Damodar breaking away to the south.

This change in the Damodar probably did good to the Hooghly as although the river has contracted at and above Calcutta, it is not now called upon to dispose of the coarse sand brought in by the Damodar: on the other hand complications have arisen in the Falta-Hooghly Point reach as shown by the abnormality in the vicinity of the James and Mary Shoal.

SILT DISTRIBUTION AND ADVANCE OF THE DELTA FACE.

It will be understood that all the changes that have been mentioned have affected the distribution of the silt supplies brought down by the rivers: previous to the time the Ganges changed its course that river must have distributed its waters fairly evenly over the whole of its delta and the presumption is that the delta face advanced out to sea at more or less an equal rate along the sea face: there may have been a somewhat greater advance on the

western side due to the additional deposits brought in by the Chota Nagpur rivers, and probably on the eastern side the progress was slower due to the fact that the Meghna carries clearer water: in fact, the western portion of the delta is somewhat further advanced than the rest. Much of the silt of course never reached the sea as it was deposited on the land to raise its level but when the Ganges went eastwards to Goalundo the majority of the silt went with it, and all these large rivers now discharge the major portion of their silt contents in the north eastern corner of the Bay: the Hooghly continues in operation on the western side, still carrying a supply from the Chota Nagpur hills and its own feeders from the Ganges: it will be noticed that on both sides of the Bay there is a delta plinth and both, so far as can be seen, are gradually approaching one another: between them is a long narrow gorge as yet unfilled called the "Swatch of No Ground." This swatch has been assumed by some to be the outcome of subsidence, but this theory has, I believe, been disputed by geologists, and it seems to me that it can be accounted for by the fact that the two delta plinths are filling in the bed of the Bay and as yet have not met, so that a deep hollow still remains unfilled.

THE TIDES.

Mention of the Swatch brings me to the question of the part played by the tides on the river system. The Swatch is a regulator of the tides: the first of the flood makes through it and then spreads, the flood along the Chittagong coast arriving later: the tidal wave passes up the various rivers and in those which carry a large supply of upland water is damped down during the freshets, so that tidal action does not travel so far inland at that season of the year as in the dry season. In other rivers which discharge a small quantity of fresh water from local areas only, the tidal currents will be found to be the most violent of any in the delta.

Between the Hooghly on the west and the Pussur at Khulna, the Jaboona is the only river which carries spill water from the Ganges through the tidal area and it is in this area that tidal action predominates. Provided the tidal wave is not obstructed by a sudden narrowing of the river, the high tide levels decrease as the wave passes up, and it therefore follows that in cases in which the tides are free to spill the land nearest the seaface must be higher than that further inland. The level of the land near the seaface is actually higher than that in the latitude of Calcutta where many of the tidal rivers have their origin in low lands or bhils: there is for instance a large group of bhils to the north-west of Khulna, the supply of fresh spill water to which is cut off by the high banks of the old Bhairab. When the tides are running high in the monsoon and the bhils have filled with rainwater, a tidal spill

from the south takes place into the bhils and is gradually reclaiming them: the tidal currents are moderately strong and the rivers run deep and are among the best in the delta: I have measured up to 165 feet of water in these rivers: soundings of 100 feet are fairly common: many of the old fresh water delta builders will be found in this area and can be recognised at once by their tortuosity; but they are in most cases of little use as carriers of the tidal wave, because the wave seeks out the least line of resistance and follows the shortest course: thus a network of comparatively straight tidal rivers will be found which have cut across the older delta builders and severed them into short lengths, which are disappearing one by one because the tides passing into them at either end, form tidal meeting grounds. These old delta builders will not as a rule be traced below a certain latitude, because they have been destroyed and covered up by the deltaic action carried on by the tides.

RECLAMATION.

I now turn to the question of reclamation of the tidal areas. Along the seaface the land used to be covered with Sunderbans forest right across the delta. As the land became raised attempts were made to cultivate it: where the water in the rivers was salt, reclamation could not be done, except by erecting embankments along the margins of the tidal rivers: thus the natural spill was cut off and the flood tide had no area on which to deposit the silt held in suspension, except on the beds of the rivers themselves: deterioration rapidly set in, showing itself at first in the head reaches, but extending rapidly towards the seaface: reclamation west of the Thackeran has now reached the seaface itself with the result that there is nothing to keep the rivers open: the other rivers on the east of the Thackeran up to the Matla are passing through the same phase, but deterioration is not so advanced. In the Subtarmukhi the silt banks now extend to the seaface and at the point where the steamer route crosses the river, where it is two miles wide, the channel is so filled with accretions that three fourths the river is high and dry at low water springs. The same fate has overtaken the Bidyadhari due to the reclamation of the salt lakes to the east of Calcutta by embankments for fishing purposes, which have shut out the normal tidal spill.

INCREASE IN TIDAL RANGES.

Another effect of embanking has been to increase the tidal ranges: as the water is confined between embankments and cannot spread laterally the high tide levels have been forced to rise several feet: a very good example is that of the Matla: At Port Canning

the highest tides rise nearly 10 feet above the surrounding country. The sudden contraction at this place opposes the progress of the flood tide and causes the high water to reach a maximum level on the whole river : the high tide line therefore rises higher and higher from the seaface to Canning, beyond which it falls rapidly up to the head of the river near Calcutta, where the levels in springs are about 5 feet lower.

EFFECT OF SPILL ON TIDAL RANGES.

When tidal rivers can spill freely it will be found that the tidal curves are different to those of rivers fully embanked. The spill prevents the levels rising beyond a certain point and the top of the curve is cut off and flattened : in fact, it is possible by examining the curve of any river to say at once whether there is any spill of appreciable volume : and it is also possible to forecast the level to which the tide would rise if the river was completely embanked and all spill cut off. In the case of the Passur, for instance, I estimate that high water springs would rise between 4 and 5 feet : this river has a good deal of spill at present.

RELATION BETWEEN RECLAMATION AND DRAINAGE.

When tidal rivers expire their beds silt up to practically high water mark and form a ring fence round the land on their banks : if the level of the land has been prevented from rising by embankments the land will remain as a waterlogged area because all means of drainage will have been closed : this is the case at present at the head of the Bidyadhari : a position of this nature is extremely difficult and costly to deal with, because drainage has to be conducted a long distance before a suitable outfall can be found, and the drainage head is so small that it is necessary to excavate very large channels.

VARIATION IN TIDAL RANGES.

From what has been said it will be gathered that the tidal ranges differ in different rivers : at Port Canning the maximum rise and fall of 21 feet takes place : on the east in the same latitude and south of Khulna the range is only 6 to 8 feet. It will be seen that in the areas in which reclamation is most advanced the maximum ranges will be found and it is in this area that decay of the river system has advanced almost to the point of extinction. In a tidal creek an increase in range often connotes an early death.

CROSS CHANNELS: TIDAL MEETING GROUNDS.

The north and south tidal rivers as a rule outlive those which run more or less east and west : the latter rivers are kept open by

spill on to land in their immediate vicinity. When this land is reclaimed the tides entering from both ends, meet at some point in the cross channel and form a depositing ground: many rivers have been killed in this way and on this account the steamer route to Barisal had to be abandoned east of the Passur in 1913 and that *via* Khulna adopted.

There are, however, many cases in which the cross rivers are self maintaining: this is due to the fact that their directions are north east or north west and that the tide which enters at the southern mouth has time to pass through before that at the northern mouth arrives: the two important factors are the relative times of arrival of the tides in the north and south rivers at either end of the cross channel and the relative strengths of the two tidal waves.

Taking the case of the Coxali Khal, the flood tide makes into the khal from the Jaboona at the western mouth first and almost reaches the eastern mouth before that from the Golgoosia arrives: the latter tide actually does enter for about half an hour and if the strength of the two waves was the same there would be a meeting ground: as however the wave from the Jaboona is much stronger, it predominates over that from the Golgoosia with the result that the latter is again pushed out and a through current is established.

CHANGES IN COURSE CAUSED BY INTERFERENCE

Before I proceed to classify the rivers mention may be made of a few cases in which interference with rivers has brought about considerable changes. Cuts across bends of rivers or joining two rivers should not be made until the effect of them has been fully studied: a good many years ago a cut was made between the Bhairab at Khulna and the Pussur which has led to all water in this locality being diverted to the south: though this cut probably had a good deal to do with the opening of the Attarabanka and brought in a supply of fresh water, thus doing an immense amount of good, it led to the death of several rivers to the east, such as the Alaipur Khal and Kachooa.

The Halifax Cut, made in 1902 by the District Board of Jessore, has also done immense good to the country on the west of the Madhumati, but the water extracted undoubtedly caused shoaling in the latter river.

The cut which was made a good many years ago to join the Hooghly (Adiganga) with the Saraswati at Sankrail was probably the cause of the death of Tolly's Nala and also the Saraswati: this cut is now called Garden Reach.

Sometimes rivers cut through the necks of bends unaided: this is brought about by erosion and spill across the neck: the effect of a cutoff of this kind may extend for many miles up and down stream: in the monsoon of 1893 the Gopalganj loop of the Madhumati cut through and the river has not yet become steady.

CLASSIFICATION OF THE RIVERS.

The rivers of Bengal can be classified into eight groups as shown below:—

TYPE 1. Rivers emanating from the hills which possess the characteristics of hill torrents. These rivers carry immense quantities of *detritus*, are subject to short violent floods and form interior deltas. Most of them spill over the country in the lower reaches, where in many cases they are embanked. As the land is raised they extend their deltas inland and are liable to sudden irruptions at the heads of the deltas. Types are the Tista, Damodar, Adjai, Cossye etc.

TYPE 2. Active fresh water delta building rivers which are perennial. This group includes the Ganges, Padma and Megna and some of their spill channels, which in the flood season spill their water over the banks, depositing a layer of silt on the land: they continue throughout the dry season to discharge moderate quantities of water down their channels and are therefore navigable throughout the year to a greater or lesser degree. The spill channels are very tortuous and are liable to sudden changes in the positions of their offtakes, and it can never be stated with certainty where the heads will be located after the floods subside. The Gorai, Madhumati, Attarabanka, Moynacotta and Naria are rivers belonging to this type.

TYPE 3. Fresh water delta building rivers which are active in the flood season only. This type is similar to those under type (2), except that the discharge takes place in the flood season only and is then cut off by bars at the offtakes; examples are the Bhagirathi, Jalanji and Mathabanga and sometimes the Moynacotta.

TYPE 4. Inactive fresh water delta building rivers which are either dead or carry only local drainage. The rivers included under this head were at one time of the active delta building types (2) or (3): due to changes, in many cases by new spill rivers opening across them and beheading them, their connexions with the parent stream have been severed and the upper reaches have silted: as in the case of the Bhairab above Jessore, these rivers sometimes receive little local drainage, due to the fact that they have raised their banks higher than the interior land: in other cases they discharge local drainage in small quantities, as in the case of the Kobadak and Chitra.

TYPE 5. *Semi-fresh water and tidal rivers.* These rivers comprise the central reaches of the fresh water discharging streams: they meet tidal action which is limited in extent and during the flood season continue to discharge outwards, although the water is backed up by the tides: for instance in 1918 in the Roopsha at Khulna there was slack water at high tide on the 2nd July, after which date the floods gradually preponderated and the current continued down till the floods fell. In the dry season tidal influence predominates and a reversal of the current takes place, but in most cases the water remains sweet. Many of these rivers also tap the cross country fresh water spill and the water having been deprived of its silt, they are scoured to a deep section and are in the best condition of any in the delta. The Hooghly at Calcutta, Pussur, Bagerhat, Kaliganga, Swarupkati and Barisal rivers are examples.

TYPE 6. *Tidal rivers discharging large quantities of upland water.* These rivers form the mouths of those under type (5) and are subject to tidal action all the year round.

TYPE 7. *Tidal rivers which discharge local drainage.* These rivers are distinct and totally independent of the upland water delta building rivers. They have their sources in bhils (low swamps) generally in the latitude of Calcutta: in the monsoon they drain large local areas on the ebb and spill on the flood: in the dry season they may continue to spill at high water and generally the water turns brackish. The Kulpatooa, Habra Gong, Seepsah, Bhudder and Rampal rivers are examples.

TYPE 8. *Tidal rivers which carry no perceptible quantity of drainage, the waters of which never turn sweet.* The rivers included under this head are purely tidal in which the water never turns sweet and for the most part are situated in the Sunderbans area. Many of them were probably at one time of the same class as type 6, but owing to reclamation by embankments the spill on to the land has been cut off in the upper reaches and in some cases down to the sea: where no such interference has occurred they continue to spill salt water on to the land at high water and in doing so have raised the land near the coast, so that there is a general ground slope inland: they, therefore, retard the progress of the delta seawards. Typical cases are the Subtarmukhi, Thackeran, Peali and Matla.

DISCUSSIONS.

STRENGTH AND WEAR OF RAILS.

Mr. R. D. T. Alexander.—I have read Mr. Harvey's paper and listened to the author's lecture on it with great interest. The paper will, I feel sure, be of great use to the Institution as a whole and to the Railway Members of it in particular. The conclusion as to the most economical section of rail to be employed arrived at by Mr. Harvey and detailed in the example given on page 15, although correct in a general way, should not, I think, be accepted in its entirety. In deciding on the section of rail to be adopted, Engineers had to consider other factors apart from the initial capital cost and recurrent charges pertaining thereto. For instance on a line designed to carry fast heavy traffic, it was from a technical standpoint very important to use an heavy type of permanent way. This had been proved by experiment to give better running, less creep, and less maintenance charges for both track and rolling stock. The longer life of the heavier type of rail would be an undoubted advantage later on, as the date by which renewals had to be undertaken would be postponed for a longer period and during that period the line would be free from many of the charges which reduced the net earnings of a railway. Mr. Harvey has in his table allowed for relaying charges but no allowance has been made for the dislocation of traffic which resulted when relaying had to be carried out. The cost of this dislocation was difficult to estimate but it represented a considerable sum to the railway administration. Similarly " pulling back " owing to creep, which is more likely to occur with a light than heavy section of rail, also caused dislocation to the running of traffic, and on important lines every effort should be made to obviate this bug bear to railway Engineers. In deciding on the type of permanent way to be employed, I am of opinion that in addition to the financial aspect of the case as worked out by Mr. Harvey, the points mentioned should be given most careful consideration.

Mr. A. T. Weston.—"We can well appreciate Mr. Harvey's position. His duty is to scrutinise with the eye of a technical expert the various proposals submitted by Railway Engineers for replacing permanent way and the many grounds on which such proposals

are urged. Mr. Harvey obviously wants a standardised set of conditions which he can impose upon such proposals. In all seriousness, however, I would ask him if he really believes that statistical information intended to cover a period of time ranging up to 30 years will have any value even after, say, an interval of 5 years, considering the fact that conditions in India, particularly in respect of personnel, change so rapidly. Any such scheme of statistics which may be launched now will be ignored or at any rate will be considered out of date by his successors in 5 years time. Judging the problem on its merits, and in view of the discussion already offered, I think there is no question that the only practical criterion to follow is to trust the common sense, experience, and competency of the Engineer on the spot and any scheme which may prejudice the value of his judgment is, I consider, unsound. While sympathising with the end which Mr. Harvey has in view we can see the danger of theoretic treatment of this subject, e.g., the diagram shows that rails are assumed to wear in a regular fashion - entirely on the top surface. In actual practice, however, the configuration of the worn surface is otherwise owing to wear from latteral flange pressure as well as vertical wear on the tread. Obviously statistics based on such assumptions would, if followed literally, lead to rails being left in service in an extremely unsatisfactory condition. For this and other reasons I think it impracticable or at any rate unsound to endeavour to control the conditions determining the replacement of permanent way on the lines put forward in the paper."

Mr. A. F. Harvey.—The points raised by Mr. Alexander certainly need consideration, but it will be found that the economic factor automatically cares for the requirements of main lines with fast and heavy traffic. When comparing lighter and heavier sections of rails for use on a particular section of line, the lighter sections will be found to be uneconomical unless they are likely to have a fairly long life of about 25 years at least in most cases. On main lines with fast and heavy traffic the gross tonnage carried per annum is bound to be large and the lighter sections of rails would obviously, therefore, have too short a probable life on such lines to be economical and the heavier sections would naturally be adopted. Frequent relaying, with its resultant dislocation of traffic, is certainly most objectionable but relaying once in about 25 years can hardly be considered as too frequent. It is not possible, when calculating the relative annual cost of different sections of rails, to include any allowance for dislocation of traffic and only the usual items, which are included in a relaying estimate, can be taken into account. The net amount of such a relaying estimate is, after all, the amount which a railway should recover before the end of the probable life of the rails by means of annual payments into a sinking fund or depreciation fund.

It appears to me that the general opinion, among those who have read this paper, is that my intention is to keep the weight of track as low as possible in every case, whereas it is just the contrary. I am strongly of opinion that, where the minimum permissible section of rail will not have a reasonably long life, it is better and in fact essential to use the heavier section straight away. This argument would apply not only as regards probable rate of annual wear due to the large gross tonnage per annum to be carried but also as regards any proposal or possibility of introducing on the section in question heavier engine axle loads than those already in use.

I have also been criticised for making no allowance for the fact that rails are usually laid in the track with the vertical axis inclined at an angle of 1 in 20. The experiments carried out in America proved that under each wheel the rail was deflected not only vertically downwards but also horizontally outwards, and the resultant pressure on the rail was evidently not vertical but inclined outwards at some unknown angle. For all practical purposes, considering the number of indeterminate factors referred to in Para 55 of the American Committee's Report, the resultant pressure on the rail may be considered as normal to the coned tread of the wheel, i.e., along the vertical axis of the rail section, as I have done in my calculations.

Another point, which has been brought to my notice privately, and regarding which it appears to be advisable to add some remarks, is the probable effect of age on the strength of rails in the track. In 1896 the Board of Trade, in the United Kingdom, appointed a Committee to enquire into "the extent of loss of strength in steel rails produced by their prolonged use on railways." Among various tests, carried out by this Committee, were tensile tests of specimen pieces taken from the heads and feet of old rails which had been in use from 10 to 20 years. The results of these tests gave an average elastic limit of nearly 23 tons per sq. inch, and an average breaking stress of about 40 tons per sq. inch. The lowest elastic limit recorded was 20·19 tons per sq. inch and the lowest breaking stress 35·82 tons per sq. inch. As my calculations of the strengths of rails are based on a working stress of 10 tons per sq. inch., this allows an ample margin for safety. The conclusion arrived at by the Committee in question was practically that, provided rails are of suitable chemical composition, etc., and free from flaws when new, they will not deteriorate appreciably in use under ordinary service conditions. The Committee in their report also referred to experiments made in order to ascertain the effect of speed on the track. They found that the deflection of the rails at 60 miles per hour was about 20% greater than the deflection at 4 miles per hour under the same engine and train.

COLLOIDAL PHENOMENA.

The President.—The author has given us an instructive paper on a theory underlying the waterproofing of cement in particular and the decay of building materials in general. He could scarcely have chosen a more suitable place than Delhi in which to deliver his lecture, as there are in the immediate environment dozens of ancient buildings so corroded away at plinth level as to be on the verge of collapse, but whether this particular corrosion is due to unstable colloidal balance, the effect of acids produced by bacterial action, or excessive original loading stresses, it is impossible now to discover.

In common with many engineers, my interest in colloidal phenomena has been principally in the fine grinding of low grade coal with oil to form a fuel and the research now being conducted with Silicagels in connection with refrigeration. The author has shown in his paper that the waterproofing of concrete is not so much the problem of preventing leaking roofs and sweating walls as that of producing in the concrete a colloidal balance as regards water to prevent the ultimate disintegration of the concrete. There is no doubt that the introduction of a colloid into concrete, which shall at once close the pores and reverse the capillarity without introducing internal stresses or reducing its strength, will produce an ideal concrete. If the metallic soaps mentioned by the author actually possess these properties, then they will prove of great value to the Civil and Structural engineer. I do not take the alarming view that all cement concrete made by the ordinary methods with well chosen and graded materials and the correct amount of water is doomed to ultimate disintegration by colloidal action, but there are a great many cases where definite waterproofing is not only desirable but imperative.

The author has dealt most carefully and lucidly with the theory of ideal waterproofing, but has only referred in general terms to the special metallic soaps. It will be of great interest if, in his reply, he will state whether these metallic soaps are manufactured commercially, and, if so, the trade name by which they are known.

The author is not a Member of this Institution, but is a distinguished engineer, paying a short visit to India, and in thanking him for his valuable paper I wish also to express the pleasure which we experience in extending to him the hospitality of the Institution.

Mr. C. B. Chartres.—(communicated). The Author has given us a highly interesting paper on the theory of making cement waterproof. I am in full agreement with the Author about the

desirability of improving concrete construction. Swelling and shrinking of concrete with changes in moisture are far greater than its expansion and contraction with changes in temperature. Concrete expands and contracts every time it is wetted and dried, and when considering ferro-concrete work it is obvious that the importance of waterproofing the concrete cannot be exaggerated.

I, therefore, welcome the paper, and the only criticism I have to make is that the Author stopped his paper too soon and did not go on to give us some results of practical experience with the metallic soaps which he appears to consider the best medium for fulfilling the conditions essential for success. I hope, however, that in the discussion on the paper some such data will be forthcoming.

I would ask the Author for instance to inform us in what form he advises the application of the metallic soap. Does it give best results when mixed with the concrete as a liquid, or is it distributed in the form of a paste which requires reducing to a liquid before mixing with the concrete, or alternatively is it best used as a powder and mixed with the cement before the addition of the aggregate?

It seems to me that in a country like India a fine powder will be better than a liquid as it will be more easy to ensure correct mixture with a powder and also it is not liable to loss by evaporation. Further it seems to me that when a metallic soap is used with water oxidisation must be set up. Is it the expansion due to such oxidisation that is relied on to fill up the pores in the concrete? If so, what happens when too much of the soap gathers together in one place instead of being evenly distributed? Disintegration would appear inevitable.

I would also like to ask what colour the soaps are in themselves and their effect on the colour of the finished structure. This is an important point where the appearance of a building is a consideration.

Again will the Author tell us the specific gravity of the soap and the quantity required to render concrete waterproof for different classes of work such as tanks, reservoirs, roofs, and cement plaster.

I personally have had experience with only one article of the kind mentioned in the paper. This is Pudlo, described as an earthy Oleate or Fat which enters into a chemical amalgamation with cementitious substances. I find that a 2 per cent. mixture with this powder renders concrete impervious to water, and that the treated concrete is certainly not less strong than ordinary concrete.

If the Author has also had experience with this powder it would be interesting to know how it compares with the metallic soap, firstly, in their respective actions on the cement, and, secondly, in the permananey of their effects on the concrete.

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Mr. Raja Ram.—There are a few points in Mr. Oesterblom's paper, on which I would like to have some more information.

On page 54 in paragraph 1, the learned Author states that "a large amount of water may be absorbed by the colloidal dust. . . . . dry."

In this connection I seem to think that there are various states of equilibrium in which varying amounts of water may be retained, but that the boundaries for increase and decrease of water for stable conditions must be defined. I would, therefore, like to know what are the percentages of water in Colloids (of common engineering materials) which would give the greatest strength or the most stable condition. *For cement such information is available to some extent but not for other materials.

On page 57 in the penultimate paragraph the Author states that "the colloidal water is distributed over the mass through microscopic, macroscopic or sub-microscopic capillaries in the body of the gel." I would like to know whether the "action of capillarity" in expelling water from a "gel" actually comes into play? Is it not some different kind of action?

On page 58 in paragraph 1 Mr. Oesterblom states that "Manufactured iron and other metals are also colloidal in nature—their structure is denser, and colloidal investigations, therefore, at present of relatively less interest."

Is it an admitted fact that iron and manufactured metals are really colloidal? Are they not a mixture of crystalloids and colloids in certain proportions?

Mr. T. H. Richardson.—It is a fairly common experience to find when heavy rain occurs after a long period of hot and dry weather that a newly constructed terraced roof (lime and soorkee concrete) leaks at the first onset of the rains. If the roof has been well constructed, it is generally found that the leakage stops after a short period and does not re-occur in subsequent years.

The taking up of the roof may be due to some such action in the concrete as has been described by the Author, but the important point is that there is no evidence of the subsequent shrinkage, the roof is water-tight after subsequent hot seasons. It would appear for such class of work that if you can keep your Sub-Overseer on the roof during construction, no addition to the concrete is necessary; while if the work is not properly supervised, any money spent on special dopes would obviously be waste of money.

Mr. McGlashan.—Mr. Chartres has already covered most of the questions I should have liked to have asked the Author of the paper and the Author's reply will be of considerable interest as I am

carrying out a large amount of concrete work in Calcutta. We have used "Pudlo" to a certain extent but not yet sufficiently to arrive at a very definite conclusion regarding it. I was at one time strongly urged to use a patent waterproofing material on the roof of my house which was a flat lime concrete terraced one and which had begun to leak during the rains, but the material got through the terracing on to the steel joists and kept dropping through and staining furniture and floors.

Mr. G. N. Gokhale.—I wish to bring to the notice of the Members the great trouble we have in Sind and probably in other parts of India from "Kalar." Large areas in that part are impregnated with salts—mainly chlorides and carbonates of sodium *and sometimes magnesium. These salts rise through masonry with the capillary water, and when the water evaporates on the surface, the salts crystallize in the pores of the brick and cause the best bricks to crumble to powder. In the case of new buildings damp proof courses are now put in, but there are hundreds of existing buildings where this is not possible. If the author of the paper could shed some light on this question it would be very useful.

As regards water-proofing of roofs, I think that the problem is structural, and no amount of "water-proofing" will solve the question. The main reason, I think, is the cement concrete. We allow centerings to remain in place for two or three weeks, and by that time the cement has set quite rigid. The removal of the centering alters the stresses and the beam deflects in places. Howsoever small this deflection is, it causes definite strains and hair-cracks start, which widen and are the cause of all leakage of roofs. I have tried an experiment of substituting the cement concrete by lime-concrete which sets more slowly and so there is more room for adjustment when the centering is removed. This was found quite satisfactory. In Madras the practice was to have jack arches of brick in lime and these gave very good results. When the cracks once start, no amount of "water-proofing" can meet the trouble. By whatever name they go, most of the water-proofing fillers are "coal-tar" in essence and the result of using these is that the occupant gets drops of tar on his furniture during the hot weather, in place of water during the monsoon. I do not quite like the change.

This question of water-proofing is very important and I wish to add how grateful we all are to the author of the paper for bringing it up.

Mr. Shiv Narayan.—Colloidal phenomena have been the subject of communications before Scientific Societies, and I remember having heard a paper or two on this subject at the Annual Meetings

of the Indian Science Congress. Recent books on Chemistry devote considerable space to colloids, sols, and gels. In the realm of Pure Science, crystallography and colloidal phenomena have been fruitful aids to research. It is, however, not so common to find colloids being considered in connection with Applied Science. Mr. Oesterblom's paper breaks new ground and should be particularly welcomed on that ground by those who believe in the co-operation of thinkers and workers. It is only another confirmation of the truth that knowledge pursued for its sake does enable us to gather a good harvest sooner or later when principles discovered in laboratory by scientific savants are applied by studious engineers to industrial problems. The present paper points the way to an investigation of the problem of how to delay the ravages of time and to build structures that will last practically for all time—to explain the reason for the survival through centuries of ancient pyramids, pillars, and paintings that have been praised by perplexed pilgrims who have sought in vain to learn the secret of their successful stand against the forces of decay. Waterproof paint is suggested as an obvious aid to preservation. Was it used by the ancients? What other aids did they employ?

Mr. S. M. Abdulla.—In the Railway Quarters at Kalyan on the G. I. P. I had built cinder-mortar roofing in jack arches. The proportion of ingredients was 1 part lime to 2 parts of cinders well ground in a mortar mill.

In the first monsoon all the roofing leaked very badly, to stop this Pudlo was applied mixed with 2 parts cement in ½″ thick plaster all over the roof. This stopped the leakage and there was no further complaint.

The cracks in plaster during the hot season were repaired with cement mortar.

Mr. Mawson.—My experience has been that Portland Cement Concrete, if properly proportioned and executed with suitable materials, great care, and skilled supervision and labour, proved to be both watertight and impermeable and required no additional colloidal mixture for internal waterproofing. Does not the Author consider the water content as most important and condemn the modern practice of using excess water when mixing to enable the concrete to *flow* into position instead of being properly mixed with the correct proportion of water and placed in position and tamped properly.

Mr. E. Webb.—"I would like to support the remarks of several previous speakers by emphasising that no amount of patent filling or lubricant in the form of Metallic Soaps such as Pudlo,

Toxement, Truscon, etc., will render concrete dense and water-tight unless the aggregate be properly graded sand suitable in size and texture and free from organic matter and the water quantity correct. Likewise, the mixing, pouring, and tamping must be properly and thoroughly carried out and "scamping" of either of these essentials can never be compensated for by the addition of patent colloidal preparations. However, I am of opinion that the Metallic Soaps referred to by the Lecturer are really useful in water-proofing reservoirs, tanks, and similar structures for holding water and, also, that their use in ordinary reinforced concrete construction is a valuable insurance against early and unexpected decay of the steel reinforcement."

Mr. B. Anantacharya.—Cracks and subsequent leakage in cement concrete of roofing, flooring, etc., can be stopped by using a richer concrete mixture of say 1-1-2, properly graded and well mixed for the topmost layer exposed to the sun's heat with light reinforcement. This experiment was actually tried in the case of a leaky flat roof in Thana. A 2″ layer of cement and gravel concrete was laid with light 1/8″ wire reinforcement 4″ apart. The leakage has now entirely stopped.

This method seems to be very much preferable to the external applications as the latter are likely to hinder also further setting of concrete though to a small extent as all subsequent absorption of moisture from atmosphere will be shut off.

Mr. I. Oesterblom.—If I may be permitted to do so it would be convenient to answer many of the comments by means of some general remarks, which would be suitable to most of them.

Concrete and the preservation of concrete seems to have been in the mind of most in discussing the paper—as indeed it was in the mind of the writer—and it was well that emphasis was placed on concrete, although it should not be forgotten that the paper has a much broader significance.

With few exceptions, however, the problem of waterproofing roofs seems to have been the one that has offered the greatest interest. And this is really turning the problem upside down. It has always been my contention that a roof cannot be properly waterproofed by adding any waterproofing substance to the concrete. Mr. Gokhale expressed the same idea when he pointed out that the problem was chiefly a structural problem. No matter how impervious the concrete, cracks are sure to occur for reasons that have nothing to do with the waterproofing of the mass; through these cracks will then pass the water and all efforts to waterproof will

then have been in vain. There is only one proper method to water proof a roof and that is to use an elastic covering on top of the concrete. This elastic covering will then follow the changes in the concrete whether these be caused by variations in temperature, structural strains, or colloidal transformations.

Still it might be worth while to point out that if absolute dryness is not required it might be sufficient to waterproof the mass of the concrete, which is undoubtedly the cheapest of all processes. It was being done during the war by the British Authorities, who purchased from the company I represent large quantities of concrete waterproofing for roof construction. They did so against our advice, and fully realizing that the responsibility for failure would be their own, later on they declared that they were satisfied with the results. Presumably the construction was not intended to be permanent.

While I am pointing out these things as a matter of mild protest I am even more anxious to deflect attention to foundation problems. Here is where serious destruction very often occurs and evidently with the most disastrous results. Unfortunately foundations are always concealed so that news about a coming disaster is therefore very unexpected and very sudden. Reconstruction of foundations under some large buildings in America is not entirely unknown, although the fact usually is kept very secret. Obviously those Architects or Engineers who have once seen the disastrous results are very careful thereafter to safeguard their foundations to the very utmost. It is cheap to use the necessary safeguards in advance; it is expensive to rebuild the foundations afterwards.

The general tone of all the comments seem to have been to emphasize the necessity for good materials and good workmanship. This of course is what one might expect in this assembly; still it is a pleasure to hear it. If it should be thought, however, that the waterproofing of concrete were intended as a substitute for good materials and workmanship a protest would be in order.

The waterproofing of concrete is intended as a still further improvement on good concrete: even the best of good concrete is not good enough until it has been waterproofed. What I have just said is not to be taken as a criticism against even the best engineer: for reasons colloidal, which I have explained in my paper, it is in the nature of concrete to be porous. This porosity may be due to working conditions, but is even more so due to unavoidable colloidal conditions, which must be met and should not be avoided.

While I agree with Mr. Mawson in his appeal for good concrete and specially wish to support him in urging dryer mixtures and more ramming I believe him to be wrong in thinking good concrete alone as good enough for permeability. My answer to Mr. Mawson

on this point is contained in my paper : it is the water in the concrete, which ultimately destroys it, that makes the concrete at the same time have the appearance of tightness. The appearance is an illusion : it is a temporary tightness which signifies the presence of a very heavy internal stress.

For Mr. Chartres' comment that I have stopped my paper too soon I am specially thankful : this I can only take as a compliment. I had always thought that for this subject the discussion would be more important than the paper ; the purpose of the paper should be only to direct the thoughts of the meeting along these somewhat new lines, which I hoped would be fruitful not only for the meeting, but also for further study. Many points of practical significance have already been brought out during the discussion. As a specific answer to Mr. Chartres I beg to add the following :—

It is my opinion that a paste added to the water is the best means to secure uniform results. It is easy to mix the paste uniformly with the water and to see that it has been uniformly mixed ; it is easy also to obtain uniform mix of the aggregates and the water. But the same is not true about a powder, whether same be mixed with the cement or the water. The company I represent tried it fifteen years ago with very unsatisfactory results. In regard to oxidisation it is my belief that same would not occur with the metallic soaps. These are fully saturated compounds and would not break down except under the effect of strong re-agents and under specially favourable conditions. The specific gravity of the metallic soaps I do not know ; the quantity required is very small : from five to eight pounds per cubic yard—the weight of the concrete would therefore be very little affected by the addition. The colour is very neutral, almost the same as for cement.

In answer to the specific question of the Chairman I beg to state that the compound I have had in mind as representing the farthest development of the science of waterproofing is the "Truscon Waterproofing Paste."

Mr. Shiv Narayan discusses like a true philosopher. He is looking far ahead and he is also trying to judge from the past. I take it that his questions are not for the speaker but rather for the profession as a whole. They are well worthy of consideration.

Mr. Gokhale's problem with capillary water in the walls of the buildings in Sind is no different from other problems of water rising in the walls except that the water is saturated with salt solutions. There is only one proper way of curing an ailment of this sort and that is to build a waterstop in sections through the entire building.

Ordinarily the capillary water is alkaline through travelling through masonry; a temporary protection can then be applied on the inside by using an anti-alkaline paint. Water will still rise in the wall, but it will come to the surface on the outside only. This is always an unhealthy condition and a waterstop is very much to be preferred. As I do not know of any reliable paint to resist the salts mentioned I can only recommend for the conditions described that a waterstop should be built in.

Mr. Webb is perfectly correct when he says that no amount of waterproofing will take the place of good concrete. If he should think, however, that good concrete will take the place of waterproofing I must refer him to the answer I have already given to Mr. Mawson on the same subject. In Singapore recently I challenged one of the P.W.D. engineers to prove his statement that he could make impervious concrete. He mixed the best concrete he knew how, to all appearances too dry for hydration, placed it on a road-surface six inches thick only, and then had it rammed for one hour, until it appeared wet all the way through, by a gang of coolies standing so close together that there was no room for another. After the concrete had been set absorbtion tests were made and it was found that one and one half per cent. by volume represented voids, which had been filled with water. If the same slab of concrete had been used as a waterstop it would have acted perfectly. Through the absorbed water and the colloidal expansion all the pores would have been closed. The usual phenomenon: Watersoaked concrete acting as a waterstop. We must remember, however, that watersoaked concrete has no permanent structural value.

Mr. Raja Ram raises some questions regarding the nature of the colloidal phenomena. We can hardly talk about transmutations from Colloids to Crystalloids or *vice versa*. It is merely a question of the prevailing conditions and specially the extent of granulation of the colloidal dust. On this depends the amount of surface energy, and on this again it seems to depend, if the material is going to act as a crystalloid or a colloid. Capillaries have nothing to do directly with colloidal phenomena; they merely serve as conveyors for the water or any other disperse medium. Iron has been studied chiefly from a crystallic point of view, but the question may well be raised if much of the mass which is now considered as crystallic, but of extremely small size, is not truly colloidal material. How else are we going to explain the extreme density of this material? The difference of behaviour of different kinds of cement from a colloidal point of view would undoubtedly be an interesting scientific problem; it is a problem of the future about which the speaker can give no information.

NOTE IN REGARD TO BIBLIOGRAPHY.

Several books and monographs have been reviewed. The following I have found specially useful and would recommend for every engineer's library :—

Two pamphlets by Dr. W. Michaelis on the Hardening of Cement (Chicago 1907 and 1909).

One pamphlet by Dr. A. E. Toernebohm " Uber Die Petrographie des Portland Zements " (Stockholm 1897).

Several Papers by Prof. Alfred H. White and specially "Integral Waterproofing for Concrete" (New York 1923).

" An Introduction to the Physics and Chemistry of Colloids " by Emil Hatcheck (London 1922). This is a small, very well written, and very useful book.

" Elements of Engineering Geology " by Ries and Watson (New York 1921). An excellent standard book.

The following are books on a larger scale for more advanced study :—

" Outlines of Physical Chemistry " by G. Senter (London 1923). A very good standard book in its 11th edition.

" The Chemistry of Colloids " by Richard Zsigmondy. Theoretical, with many engineering applications (New York 1917).

"A Handbook of Colloid Chemistry" by Dr. W. Ostwald (London 1919). A well known book, chiefly theory.

" Theoretical & Applied Colloid Chemistry " by Dr. W. Ostwald (New York 1922). A series of lectures mostly about technical applications.

" Kappilar Chemie by H. Freundlich (1920). Well known but personally unknown to the Author.

" Applied Colloid Chemistry " by W. D. Bancroft (New York 1921). A most excellent practical book.

"Protein and the Theory of Colloidal Behaviour" by Jacques Loeb (New York 1922). Chiefly for Biologists, contains also general information.

"Monographs on the Physics and Chemistry of Colloids " by The Svedberg (London 1922), etc. Extremely well written, but chiefly theoretical. Three monographs, or possibly more, have been published.

***Note.*—Ostwald's and Zsigmondy's books are translations from the German.**

JAMSHEDPUR SEWAGE DISPOSAL WORKS.

Mr. R. Wolfenden.—I think it is very appropriate that I should say something on this paper, as we have recently started up an "Activated Sludge Plant" at the Bengal Engineering College, and as I have been watching its operation since the beginning of November last. The plant is still under the charge of Public Health Department of Bengal, but will ultimately come under the care of the college authorities, and will work under the supervision of myself as Professor of Mechanical Engineering and Superintendent of Workshops. Although, therefore, not in actual charge of the plant at present, I have been following its working with close interest, and latterly with some degree of anxiety. Perhaps I had better give first of all a history of the works. The design of the tanks was done by the same people who have designed Jamshedpur works. The construction began somewhat about the same time as the construction on the Jamshedpur scheme. No money was, however, allotted by the Government for the completion of the works until late in 1923 so that the whole scheme has been held up until 1924. There were further troubles about starting and maintenance last year, so that the plant did not begin to function until the beginning of November of last year. As the plant would finally have to work under the college authorities, the appointment of staff to run the plant was left to the College.

I had considerable difficulty in getting an assistant to take charge of the plant. I interviewed nearly 120 candidates, most of whom were Indians, and practically all of them withdrew when they saw the nature of the work. The prospect of having to supervise, the repair of valves, or to keep machinery which actually dealt with sewage in proper order, was sufficient to deter most of the candidates from taking the post. This difficulty may not be felt so much outside Bengal, but it certainly operated strongly in that province. It has also been almost impossible to get fitter mistries in connection with this work. Since November there have been several engaged, but they all left when anything was wrong, the reason being that in Bengal mistries are strong caste men. However, we have now got a suitable assistant in charge, although the mistry problem has not yet been satisfactorily settled. The plant is designed for 1,200 people, but when the plant was started up there were only about 450 people in the compound. The plant was designed on very similar lines as the Jamshedpur plant. The blowers deliver against a pressure of 4 lbs. per square inch. From 8 to 11-30 A.M. and from 12-30 to 4 P.M. and from 5-30 to 11 P.M. the blowers are driven by

electric motors as during those hours our main power plant is working. From 11-30 A.M. to 12-30 P.M. and from 4 to 5-30 P.M. the power plant is stopped so that during those hours the blowers are driven by a 8½ B. H. P. Campbell Crude Oil Engine. In Mr. Temple's paper he mentions that he had trouble with his oil Engine and also mentions that his Engines are not correctly proportioned for the work and are not running economically.

I have had a certain amount of trouble with our own small engine driving the blowers. As it is too powerful for the work and because of the very light load it carbonises badly.

We have tried all sorts of mixtures but cannot get rid of excessive carbonisation, and there seems to be no doubt that it is due to the engine running on a much smaller load than that for which it is designed.

I should like to give a fairly detailed account of what has happened in the sludge tanks. I wish to emphasise that the sludge tank is not under our charge and therefore my account is that of an interested observer, but one to whom the results are of vital importance as we ultimately have to accept the scheme from the Public Health Department.

The Plant was started up by filling the tanks with water and the blowers were operated and aerated the water.

The sewage was admitted gradually and the manner of operating the plant was as follows :—

Sewage was pumped into the tanks from 8 to 9 A.M. and then no further pumping took place until 2 P.M. when pumping again took place for one hour.

Aeration took place from 8 A.M. to 6 P.M. continuously, the plant being shut down at 6 P.M. The liquor in the chamber immediately before the settling chamber was tested twice a day, and after about a week's aeration sludge settled out when the testing flask was allowed to stand for about one hour.

By the middle of December the amount of this sludge had reached about 4%. Tests were made for ammonia and nitrites. A few drops of Nessler's solution should give a yellow colouration if Ammonia is present.

1 c.c. of Sulphanilic acid and 1 c.c. of Naphthylamine gives a crimson colouration on standing from 5 to 10 minutes if nitrites are present.

The tests first showed that ammonia and nitrites were present in the effluent in abundance; but by the middle of December they were present only in slight traces. The effluent was fairly clear.

At the beginning of January the population of the compound was increased by about 150 people. For the first few days the chemical tests of the effluent showed increased traces of ammonia and nitrites but later these traces became faint.

The aeration sludge did not increase beyond 4%.

The sewage is now pumped for 15 or 20 minutes and then pumping is stopped for two hours after which pumping again takes place for 20 minutes and then stops for two hours and so on throughout the day. The aeration takes place continuously from 8 A.M. to 11 P.M., that is, the working of the blowers is increased by a period of 5 hours. Since that time the effluent has contained a diminishing sludge content. A flask of effluent after standing for one hour contains considerably less than 2 per cent. of the sludge. The liquor is fairly highly coloured compared with what it was, although there is very little smell. It seems to me that these conditions indicate that the sewage is overblown. Mr. Temple on page 75 says: "When a sewage is overblown which occurs when the quantity is to be treated is too little for the tank, the sludge burns out and diminishes in volume and the effluent becomes colloidal."

I should like Mr. Temple's observation on this point. Mr. Temple has also said on the same page: "It has been established that there is a minimum and maximum period of aeration for any particular sewage, and there is also a minimum and maximum percentage of sludge to be introduced into the sewage if a clear and stable effluent is to be produced."

In the College plant there does not seem to be any accurate method of regulating the percentage of sludge introduced into sewage. There has been great difficulty as regards the diffusers. The diffusers have been covered with a silty deposit, and it has been very difficult to keep them from rapidly choking. They have been cleaned by blowing compressed air through them, as there is an air compressor in the College. I should like to ask Mr. Temple about the influence of the hardness of the water both on the deposition of silt and on the formation of the sludge. The water at the College is taken from the Hooghly river and is very hard. At present it has a temporary hardness of 8·5 and a permanent hardness of 14·5, giving a total hardness of 23. It goes up, however, in the hot weather to as much as 35. The sulphates present are copious. It seems to me that these facts will have a very considerable influence on the working of such a plant. I am a mechanical engineer with no previous knowledge of sewage disposal, and I should like Mr. Temple's observations on this point. I may say that the sewage is reported by the chemist sent by the Patterson Engineering Coy. to be particularly strong, very much stronger than at Bangalore, where there is an

activated sludge plant successfully working. He reports that all the urine seems to find its way into the sewers which is unusual with an Indian sewerage plant of any kind.

From my own observations and from Mr. Temple's paper it seems to me that this process requires an expert chemist and a bacteriologist on the plant. Mr. Temple's own plant has been working for 2 or 3 years and his paper indicates that even now there are difficulties which necessitate constant and expert supervision of the plant, which makes such a system unsuitable for Moffusil stations, and which adds to the expense of the sewage disposal. The space occupied by the disposal tank is of course much smaller in the Activated Sludge System, and the system is therefore valuable and important in large towns where land is very valuable.

I am very pleased to be able to hear Mr. Temple's paper as his experiences recorded in it will be a most valuable help to other people connected with new Activated Sludge Plant Schemes.

Mr. F. C. Temple.—The only information we have regarding the Sibpur Activated Sludge Plant is that given in Mr. G. Bransby Williams' new book on Sewage Disposal in India and the East. From that it appears that the total capacity of the aeration tanks is 3,448 c.ft. to which must be added the 190 c.ft. of the disintegrating tank, for the sewage is mixed with the return sludge before it enters that, and aeration commences there. The total aeration tank capacity is therefore 3,638 c.ft. Allowing for 20% sludge constantly maintained in the tanks (and it is extremely unlikely that a greater percentage will be attainable even if desired), the aerating capacity would be 2,913 c.ft. which is large enough to deal with the sewage of 1,500 persons at least. At the time when Activated Sludge Ltd. were designing this tank they paid very little attention to the relation of tank capacity to the number of users and only worked on the volume of liquid. Seeing that the total population served is now only about 600 persons it is hopeless to expect that the tank will work properly unless some part of the aerating capacity is cut out. There should be very little difficulty in re-arranging the tanks so that this can be done. The first length of tank which extends the full 72 ft. would probably be ample. All the indications given in Mr. Wolfenden's remarks point to the burning up of the sludge by over-blowing, or to the possibility that no sludge is now being formed for want of a sufficient nucleus. The fact that about 4% sludge was formed when the blowing periods were shorter and that the sludge has diminished since the blowing periods were lengthened supports this view. All of this emphasizes the necessity, which we have frequently been at much pains to demonstrate, of proportioning the size of the plant correctly for the work that it has to do and for the necessity of measuring that work by the amount of putrefactive

matter to be purified, or in other words by the number of people served.

Mr. Wolfenden mentions that there are frequent accumulations of silt on the diffusers. This is to be expected when the blowing is intermittent, with long periods of rest, as it is even now, the plant being shut down at night. To keep the diffusers clear, blowing must be continuous or very nearly continuous (the use of Pulsating Gear would not be considered as making the blowing intermittent from this point of view). Our experience shows that intermittent blowing even on an intermittent supply of sewage is bad for the working of the tank not only in causing accumulations of silt on the diffusers but also in upsetting the bacteriological and chemical action. To make the Sibpur Installation a success, it will be necessary to reduce the aerating capacity and to arrange for continuous aeration night and day.

Mr. Wolfenden says that the plant was designed on "very similar lines to the Jamshedpur Plant." Superficially this is true. There are, however, some very important variations between the two designs. The Sibpur Plant contains a disintegrating tank; the Jamshedpur plant does not. We have been able to obtain no information regarding the working of this pattern of disintegrating tank. It was fitted in the Moreton Plant, but no reference has been made, that we can find, to its working there. It has not been fitted to any of the Manchester Installations. At one time we considered the desirability of adding it to the Jamshedpur Plant, but on careful examination we were very far from being convinced that its design is satisfactory. It would be interesting to bye-pass it in the Sibpur Plant and see what difference occurs in consequence in the working of the plant.

In the Jamshedpur Plant it is possible to bye-pass 1/3rd or 2/3rds of the aerating tanks at will. No such provision has been made in the Sibpur Plant. We consider that provision of this kind is essential.

In the Sibpur Plant the return of the sludge from the bottom of the settling hopper to the re aerating chamber is by gravity: in the Jamshedpur plant it is by an air-lift. This is probably one of the most important differences in the design of the two plants. We have found control of the volume of return sludge of the greatest possible value. From the drawing it appears that it would not be very difficult to instal it in the Sibpur Plant and it would certainly be worth while to do so.

The intermittent supply of sewage at Sibpur should not seriously affect the working of the plant unless the volume pumped in at any one time is so great in proportion to the volume in the tank as to

cause short-circuiting and discharge of unpurified sewage at the outlet. Continuous flow of sewage is undoubtedly convenient for even working of any plant, but at Jamshedpur, where the flow is almost continuous, the strength of the sewage varies very greatly at different times of the day. The statement by the chemist of the Paterson Engineering Co. that the sewage is very strong is of no use for purposes of comparison as no figures are given in support of it.

We do not think that the hardness of the water is likely to affect the sludge, though this is possible. We think that probably the sulphates will pass out with the effluent.

We agree with Mr. Wolfenden that the process requires supervision by an expert bactériological chemist. The system in its present form is certainly not suitable for small mofussil stations, which cannot afford to retain such a man. The full value of the system cannot be realized unless full value can be obtained from the use of its products, namely, the effluent for irrigation and the sludge as a fertiliser. Under suitable conditions, namely, the presence of a large enough quantity of sewage to justify overhead charges in the employment of really skilled men, suitable lands to be cultivated and a market for the crops, the system already begins to compare favourably with other systems, but it is not suitable where some cheap method of rendering a small quantity of sewage fit to throw into a large quantity of river water is required.

CONDENSER TUBES, LOCOMOTIVE TUBES AND CUPRO-NICKEL.

The President.—The careful and detailed description which the author has given of the manufacture and properties of cupro-nickel will prove of great value to those of us in India, who are users of this comparatively new material.

Some 20 years ago, I was interested in a somewhat intricate valve gear where the superheat and velocity of the steam were comparatively great and in the construction of which all yellow metal alloys had failed. It was decided to try to cast the parts from an alloy of Nickel and Copper and although many varied percentages and temperatures were tried, all the castings came out coarse, porous and useless. It is clear that great advances have been made by the chemists and metallurgists since that time and I wish to ask the author whether modern Cupro-Nickel can readily be cast for small special parts, and if so whether the castings are clean and close grained and whether any special precautions are necessary.

The corrosion and erosion of condenser and boiler tubes is a difficult and complicated problem and it is almost impossible to predict results unless conditions are exactly similar to those of which experience has already been gained. Some time ago I had experience with a surface condenser used in a chemical works to condense the steam which was mingled with gases from process evaporators. The condenser was of the ordinary type with the injection water in the tubes and the gases flowing across the tubes. Although the tubes were of a specially selected yellow metal alloy they corroded through in six weeks and new replace tubes showed heavy corrosion in one week; the corrosion in both cases was considerably more marked on the side of the tube opposed to the flow of the gases. Because of this and because time was of importance I reversed the condenser connections and caused the gases to flow through the tubes and the injection water to surround the tubes. The efficiency of the condenser was of course reduced but the vacuum obtained was still sufficient for the purpose and after two years use, the tubes show no indication of corrosion. I shall be glad to learn whether the author has had experience with condenser tubes in similar conditions and particularly whether there is any data available regarding the behaviour of Cupro-Nickel in such situations. There is urgent need for information regarding the resistivity of Cupro-Nickel to acid solutions of varying strengths. Sulphuric acid of a certain critical strength can safely be stored in Cast Iron tanks, but stronger or weaker solutions cause rapid corrosion. Monel metal, which is a natural alloy of nickel 67 per cent., copper 28 per cent. and other metals 5 per cent. has given very good results in a great number of cases with corrosive liquids, but in common with all other alloys which have come under my notice, it behaves differently with varying strengths of the same acid. If the author can give any data on this subject it will be of great value to chemical engineers and to those interested in the machinery used in dye houses and bleach works.

Mr. Shir Narayan.—I believe that recently Electric furnaces have been installed at the Jamshedpur works of the Tata Iron and Steel Company. I would like to know if these furnaces are being used to manufacture tubes of any kind. Are condenser tubes, whether of brass or of Cupro-Nickel, being made anywhere in India? If so, what is their relative cost? What would be the cost of producing brass or Cupro-Nickel tubes in India?

Mr. R. Wolfenden.—From Mr. Cameron's paper it appears that the properties of the Cupro-Nickel alloy in the proportions described are very similar to those of Rustless Iron—I mean the comparatively new stainless steel in which the carbon content is very

low and which is much easier to work than is ordinary stainless steel. Rustless iron has a finish very like silver—except that it is a little darker—and it is being used for all the ornamental purposes described by Mr. Cameron as especially suitable objects for Cupro-Nickel.

Rustless iron is much more expensive that stainless steel as it is made from carbon-free ferrochrome which is expensive. It is being tried for steam turbine blades, and in this connection I should like to ask Mr. Cameron whether Cupro-Nickel has been used for this purpose?

Also, if Cupro-Nickel has been used for steam turbine blades I should like to ask for the relative costs of stainless steel, stainless iron, and Cupro-Nickel for this work?

Also, what are the relative costs of rustless iron and Cupro-Nickel for the ornamental uses described in the paper?

I should also like to ask Mr. Cameron as to the difficulties in working this metal?

Some of the greatest difficulties in turbine blades are due to the scouring action of the steam on the blades. What effect has this action on Cupro-Nickel?

Mr. E. Webb.—"It is interesting to note that the causes of corrosion and consequent failure of Condenser and Locomotive Tubes are found operating in much the same way in steam and water turbines. In each case, the destructive action is brought about by changes in velocity and kind of flow of the fluid passing through the channels concerned. In Condensers and Steam Turbines, we are dealing with steam and with water in the case of Water Turbine. Constant changes in the magnitude and direction of the velocity of these fluids bring about corresponding changes in pressure on various surfaces with a resulting tendency to the formation of vacua and corresponding liberation of oxygen in a highly active form. This oxygen then attacks any material which is not perfectly homogeneous or inherently resistant to oxidation and this corrosion is aggravated by the abrasive action of the fluids employed which are never absolutely pure and, in the case of water turbines in India, very often are heavily charged with silt. In some machines, the changes in velocity are brought about deliberately and are controlled with a definite purpose, while in others, the changes of velocity occur in the form of eddies which are fortuitous; but, most probably, the same kind of corrosive action takes place in both cases, the difference being one of degree.

From the foregoing it will appear that the hardness of the Cupro-Nickel is an important feature and I should like to ask the Lecturer if he can give us information regarding this and, also, the casting properties of the alloy. The comparative costs of

Cupro Nickel and say phosphor bronze in the form of castings would also be useful information for consideration of the possibility of using Cupro-Nickel alloy for water turbine runners."

Mr. A. Cameron.—I am not aware that Electric furnaces are in used in India—if they are, it will be in connection with steel plates and angles only. No tubes of any kind are manufactured in India at the present time therefore the question of the relative cost of producing tubes in India does not arise.

Cupro-Nickel is a comparatively new alloy in the Non Ferrous group and has been used for purposes where a metal resistive to corrosive attack is desired. Nickel has the effect of increasing the difficulty of manipulation and the difficulty of manufacture obviously increases the cost of production so that alloys of a higher content of nickel cost considerably more than those with the lower content—the difference being greater than would be indicated by the price of the raw material. Regarding the relative cost of tubes to take one most conspicuous case Newcastle-on-Tyne Electric Supply Co.—where brass condenser tubes have been known to fail in periods as short as 6 weeks and the average life between 6 to 12 months. Cupro-Nickel tubes were introduced and have been in use for upwards of 3 years, their condition showed no signs of detriment and no single tube failed. As a consequence of this a great improvement has been effected on the working condition of this Power Station which also means a great saving in cost of maintenance. The increase in service life will only be seen when the statistics of years are available. There are a wide variety of uses in various industries for which Cupro-Nickel is eminently suitable such as valves parts for superheated and high pressure steam, turbine, blading, and shrouding, pump rods, etc.

Mr. Webb's remarks on the destruction found in steam and water turbine are extremely interesting. Blade wear is detrimental to efficiency and must be minimised in order to avoid many difficulties. Numerous experiments and tests have been carried out on a number of highly recommended blading materials and it has been found that the use of any of these depends upon six main properties namely—

1. Ability to resist erosion by steam.
2. Ability to resist corrosion.
3. Strength at high temperatures.
4. Cost of material.
5. Ease of production in the required form.
6. Resistance to fatigue.

The materials which meet those requirements are nickel-alloys such as Cupro-Nickel which is at least equal if not superior to any other available material for blading.

With regard to its casting features, the chief point is in the absolute control over the pouring temperature.

"I am much obliged to the President for his appreciative and encouraging remarks.

"Cupro-Nickel is a comparatively new alloy and as such therefore it will be some time before the statistics of years are available of its usefulness and increase in service life but of this I am convinced it has real potential value to purchasers of high class products.

"With regard to the question of its suitability for castings, for small special parts, I believe Cupro-Nickel can be used but I cannot speak from experience. The nickel content is an important factor in the alloy. As touching condenser tubes—most of the tests for resistance on Cupro-Nickel have been made on the 85/15 and 80/20 qualities in comparison with brass of Admiralty quality (70/30). Corrosion of condenser tubes is a continual problem with users of steam plant in Electric Power Stations, and such like where high condensing efficiency is desired. Cupro-Nickel of the qualities mentioned above has proved resistive to corrosion where no other metals would stand up. The most conspicuous case is that which applies to a Power Station in the north of England where brass tubes have been known to fail in six weeks and the average life six to twelve months. In this Power Station Cupro-Nickel tubes have been in use for upwards of three years and their condition shows no sign of detriment and not a single tube has failed.

"The President's experience in the use of Monel Metal and its resistance to corrosive liquids is similar to my own. For special cases the grade of the alloy should be specified.

"At the present time Cupro-Nickel is manufactured principally into condenser tubes, locomotive boiler tubes and stay rods."

THE

FIFTH ANNUAL GENERAL MEETING.

The Fifth Annual General Meeting of the Institution was held in the Y.M.C.A. Hall, Kingsway, Delhi, at 10-30 a.m. on Monday, 23rd February, 1925.

PRESENT.

Mr. C. D. M. Hindley (in the Chair).
,, R. D. T. Alexander.
,, N. N. Ayyangar.
,, H. Burkinshaw.
,, E. J. B. Greenwood.
,, D. G. Harris.
,, K. M. Kirkhope.
,, J. S. Pitkeathly.
,, G. T. Mawson.
Rao Bahadur S. V. Rajadhyaksha.
Mr. T. H. Richardson.
,, C. H. R. Thorn.
and 32 Corporate Members.
Mr. F. Powell Williams (Secretary).

PROCEEDINGS.

1. Mr. C. D. M. Hindley (President) took the Chair at 10 30 A.M.

2. The Secretary read the notice convening the Meeting.

3. The Minutes of the Fourth Annual General Meeting were read and confirmed.

4. The Annual Report of Council and the Statement of Accounts, duly certified by the Auditors, were handed to all Members present.

Mr. E. J. B. Greenwood moved that the Report and Accounts be adopted.

This was seconded by Mr. T. H. Richardson, and carried unanimously.

5. It was proposed by Rao Bahadur S. V. Rajadhyaksha that Messrs. Price, Waterhouse, Peat & Co. be re-elected Auditors at a remuneration of Rs. 250 per audit.

This was seconded by Mr. G. T. Mawson, and carried unanimously.

6. It was proposed by Mr. A. Cameron that the operation of Article 34 be extended for one year.

This was seconded by Mr. R. Wolfenden, and carried unanimously.

7. It was proposed by Mr. N. N. Ayyangar that the following Members of the Institution be elected Members of Council :—

Mr. G. Bransby Williams.
,, H. Burkinshaw.
,, G. W. Eves.
,, G. McC. Hoey.
,, A. H. Johnstone.
,, C. A. King.
,, J. W. Meares.
,, H. Nimmo.
,, C. L. Cartwright.
,, E. J. M. Hudson.
Lt.-Col. H. del. Pollard Lowsley.
Mr. N. N. Ayyangar.
,, C. Addams Williams.
,, C. B. Chartres.
Mr. K. M. Kirkhope.
Rao Bahadur S. V. Rajadhyaksha
Mr. H. P. Gibbs.
,, R. D. T. Alexander.
,, J. McGlashan.
,, G. T. Mawson.
,, W. H. Neilson.
,, C. S. C. Harrison.
Lala Jwala Prasad.
Mr. F. A. Hadow.
,, W. P. Roberts.
,, E. S. Tarlton.
,, H. P. Vidyant.

and the following Associate Member be elected an Associate Member of Council :—

Mr. Abdul Azziz.

This was seconded by Rai Bahadur Mukkhan Lal and carried unanimously.

8. The Chairman reported that the outgoing Council had unanimously elected Mr. H. Burkinshaw as President of the Institution for the year 1925-26.

That the four past Presidents are :—

Sir Rajendra Nath Mookerjee, K.C.I.E., K.C.V.O.
Lt.-Col. G. H. Willis, C.I.E., M.V.O., R.E.
Mr. A. C. Coubrough, C.B.E.
Mr. C. D. M. Hindley.

That under Article 9, the following Chairmen of Local Associations are the Vice-Presidents of the Institution :—

Bengal ...	... Mr. R. D. T. Alexander.
Bombay ...	... ,, G. T. Mawson.
United Provinces	... ,, H. P. Vidyant.
South India	Dewan Bahadur A. V. Ramalinga Aiyar.

9. The Chairman then asked Mr. H. Burkinshaw to take the Chair and read his Presidential address.

10. The President then read his Presidential address.

ANNUAL REPORT OF THE COUNCIL
FOR THE YEAR ENDING 31st AUGUST 1924.

The Council have pleasure in presenting to the members at the Fifth Annual General Meeting their Report of the progress and work of the Institution during the year ended 31st August 1924.

MEMBERSHIP.

The changes in the membership between the 31st August, 1923 and 31st August, 1924, are shown in the following table:—

	Honorary Members.	Hony Life Members.	Life Members	Members.	Life Asso. Members.	Associate Members.	Associates.	Students.	Subscribers.	TOTALS.
Membership on 31st Aug. 1923	3	2	28	269	2	285	4	64	21	678
Additions to 31st Aug. 1924	..	..	5	14	..	44	2	29	2	..
Less Deductions—										
Deceased ..	..	..	1	2		1	..	1	..	..
Resigned ..	..	..	..	21	.	3	1	6	2	..
Membership on 31st Aug. 1924	3	2	32	260	2	325	5	86	21	736
Nett Additions during the period 31st Aug. 1923 to 31st Aug. 1924.	..	..	4	-9	..	40	1	22	..	58

COUNCIL.

During the year under review certain alterations have taken place in the Constitution of the Council and Committees of the Council. Mr. A. Cochran, Mr. T. S. Dawson resigned on retiring from India. Mr. J. D. Stuart and Mr. B. C. Rowlandson resigned on proceeding on leave. Mr. C. B. Chartres, Mr. C. H. R. Thorn,

Col. H. del. Pollard-Lowsley, Mr. K. M. Kirkhope, Mr. C. Addams Williams, Mr. C. L. Cartwright, Mr. N. N. Ayyangar and Mr. E. J. M. Hudson were co-opted Members of Council.

Mr. J. W. Meares continued to act as the representative of the Council resident in England.

KELVIN CENTENARY CELEBRATIONS.

Sir Richard Glazebrook, the Chairman of the Kelvin Centenary Committee, invited the Council as representing the Engineering Community in India to appoint a delegate as a Member of the Committee of Honour and to be present at the Centenary Celebrations in July 1924. The Council appointed Mr. H. Burkinshaw as their delegate and on behalf of the Institution he presented an address at the Centenary Celebrations.

WORLD POWER CONFERENCE.

The Government of India referred the question of their representation at the World Power Conference to the Council of the Institution, and as a result of the Council's recommendation Mr. J. W. Meares was appointed delegate representing the Indian Empire.

The Institution of Electrical Engineers in London organised a programme of functions to entertain overseas Engineers attending the World Power Conference and invited the Council to appoint delegates. The Council nominated Mr. A. C. Coubrough, Mr. J. W. Meares and Mr. H. Burkinshaw, who were in England at the time to be their delegates.

The Council take this opportunity of thanking the President and Council of the Institution of Electrical Engineers for its courtesy in this matter.

STANDARD SPECIFICATIONS.

The Council continued to act as the Indian Committee of the British Engineering Standards Association.

During the year ending 31st August 1924, the undermentioned Standard Specifications were received for the consideration of the Council :—

No. 12—1920- Portland Cement.

C. A. (EL) 5561 Draft Specification for the Electrical Performance of Large Electric Generators and Motors with Class A and Class B Insulation Continuous Maximum Rating.

C. A. (EL) 5565 Draft Specification for the Electrical Performance of Large Electric Generators and Motors with Class A and Class B Insulation Continuous Rating with Sustained Overload.

C. A. (EL) 5615 British Standard List of Terms and Definitions used in Radio communication.

C. A. (A) 5663 British Standard Specification for Dimensions of Electric Lighting and Starter cables for Automobiles.

C. A. (EL) 5703 British Standard Electrical Equipments for Motor and Generator Control (for Direct Current Circuits).

C. A. (P) 6138 Draft Specification for Fuels for Heavy Oil Engines.

C. A. (EL) 6349 Draft Specification for Hard Drawn Copper Solid and Stranded Circular Conductors for Overhead Power Transmission Purposes.

C. A. (EL) 6199 B. S. S. 161 for Normal Type Tungsten Filament Electric Lamps.

C. A. (EL) 6366 2nd Draft: Revision of B. S. S. 82 Face Plate Starters.

C. A. (EL) 6605 Draft B. S. Specification for the Electrical Performance of Alternators of the Steam Turbine-driven Type with Class A and Class B Insulation.

C. A. (EL) 6828 Draft B. S. S. for the Electrical Performance of Large Electric Generators and Motors with Class A and Class B Insulation. Load-with overload Rating.

C. A. (EL) 6765 Draft B. S. S. for the Electrical Performance of Large Electric Generators and Motors with Class A and Class B Insulation. Continuous Maximum Rating.

C. A. (EL) 6902 Draft Specification for Protective Relays.

C. A. (EL) 6945 Drafts Revision of B. S. S. 81. Instrument Transformers.

C. A. (EL) 6951 Proposed Definition of Flameproof Enclosure (including Explosion-proof).

C. A. (EL) 7144 Draft Schedule of Tests of Flameproofness for various classes of apparatus to prove compliance with the definition.

C. A. (EL) 7160 Second Draft. Revision of B. S. S. No. 82. Face Plate Starters. (For Alternating Current Motors.)

Very favourable comments were made by the Secretary of the B. E. S. A. on the excellent report submitted by the Council in connection with Specification No. 12—Portland Cement—and a copy of the B. E. S. A. letter was published in Bulletin No. 7.

INTERNATIONAL ELECTRO-TECHNICAL COMMISSION.

The Council have continued to act as the Indian Committee of the I. E. C. and have dealt with a considerable number of references made by the General Secretary of the I. E. C.

The Government of India withdrew in 1923 the grant of £130 they made annually for several years, and the Council are endeavouring to raise this amount from other sources.

The Council consider that the work being done by the I. E. C. is of such great importance to India that they will continue to act as the National Committee of that body in India.

JOURNAL.

Volume IV of the Journal was published in April, 1924. It contained 212 pages and numerous plates. Many of the English Engineering Periodicals contained reviews of the Journal, and the general opinion appeared to be that it contained papers of value to the Engineering profession.

Remarks were also made as to the expeditious manner in which it was published.

In view of the fact that Members are kept fully informed of the affairs of the Institution through the medium of the Quarterly Bulletin, the Council decided to continue to issue only one copy of the Journal annually.

LIBRARY.

Steady progress has been made in the formation of the Library and the Council wish to thank Members who have given books to the Institution.

A catalogue of books in the Library is being compiled, and the Council will publish in an early issue of the Bulletin details of the books which are available for reference.

BULLETIN.

Four issues of the Bulletin were made commencing with Part 2 in September, 1923.

The Bulletin having met with general approval the Council will continue to publish it quarterly.

EXAMINATIONS.

No examinations have yet been held as the number of candidates was so few that the Council did not feel justified in holding an examination.

DONATIONS.

During the period under review a further donation to the Capital Funds of the Institution has been received from the under mentioned donor to whom the thanks of the Institution are due :—

Mr. H. H. Jellett .. ... Rs. 200 0 0.

AWARD OF PRIZES.

The Council have awarded the undermentioned prize during the year : —

H. E. The Viceroy's Prize of Rs. 500 to Mr. D. R. MacIntosh for his Paper :—

"An Examination of the New Indian Boiler Regulations, 1924."

No award of the prize of £20 offered annually by the Institution of Electrical Engineers was made.

LOCAL ASSOCIATIONS.

The Council are pleased to be able to report that steady progress is being made by Local Associations.

Meetings have been held regularly and a large number of Papers have been read and discussed.

ACCOUNTS.

The audited accounts for the period ending 31st August, 1924, are appended. The accounts show that there is a deficit on the year's working of Rs. 11,169-5-5 as against a deficit during the previous year of Rs. 11,902-5-9.

Expenditure has increased from Rs. 15,841-13 0 to Rs. 18,905-5-3. This increase is due to travelling expenses having risen from Rs. 615-13-3 to Rs. 3,097-10-0 and to increased rent, the Institution having removed its offices to larger premises at 26, Chowringhee Road. In other directions the expenditure has been reduced.

Economy has been made in several items of expenditure, and the Council believe that within two years the income will more than cover the expenditure.

The Institution of Engineers (India).

BALANCE SHEET AS AT 31ST AUGUST 1924.

LIABILITIES & SUNDRY CREDIT BALANCES.

	Rs.	A.	P.	Rs.	A.	P.
CAPITAL—						
1. *Permanent Reserve A/c.*—						
(*a*) Entrance Fees ..	52,738	5	9			
(*b*) Composition Fees (for Life Membership) ..	7,716	0	0			
(*c*) Transfer Fees ..	850	0	0			
2. *Donations*	62,213	8	0			
				1,23,517	13	9
SUBSCRIPTIONS IN ADVANCE..				2,853	0	6
LIABILITIES—						
* For Expenses . ..	836	0	0			
Bengal Association ..	1,040	14	6			
Bombay Association ..	807	6	6			
U. P. Association	701	0	0			
S. I. Association	548	0	0			
Sundry Creditors	23	0	0			
				3,956	5	0
B. E. S. A. ALLOWANCE FUND				2,999	10	10
NATIONAL ELECTRO-TECHNICAL COMMITTEE FOR INDIA				808	7	4
IMPERIAL BANK OF INDIA—						
Overdraft on Revenue A/c ..				11,094	14	9
				1,45,230	3	8

ASSETS & SUNDRY DEBIT BALANCES.

	Rs.	A.	P.	Rs.	A.	P.
FURNITURE & FITTINGS—						
As per last A/c	7,717	0	4			
Addition during the year ..	498	8	0			
				8,215	8	4
OUTSTANDINGS .				3,009	8	0
DEPOSIT . ..				25	0	0
INVESTMENTS—						
6%, 10 year Bonds 1930 ..	5,000	0	0			
Ditto 1931 .	42,500	0	0			
Ditto 1932 ..	16,000	0	0			
				63,500	0	0
CASH at Alliance Bank of Simla, Ltd. (in liquidation)—						
On Permanent Reserve A/c ..	5,351	15	0			
On Donations A/c	11,771	1	2			
On Suspense A/c* . ..	5,298	1	4			
	22,421	1	6			
Less—50 Recovered ..	11,210	8	9			
	11,210	8	9			
AT IMPERIAL BANK OF INDIA—						
On Permanent Reserve A/c ..	350	11	9			
In hand .. .	174	10	3			
				11,735	14	9
INCOME & EXPENDITURE A/c—						
Balance as per last A/c ..	44,274	15	2			
Add—Deficit for the year	14,469	5	5			
				58,744	4	7
				1,45,230	3	8

We have audited the above Balance Sheet with the Books of the Institution of Engineers (India), and have obtained all the information and explanations we have required. In our opinion such Balance Sheet is properly drawn up and exhibits a true and correct view of the Institutions affairs according to the best of our information and the explanations given to us and as shewn by the Books of the Institution.

PRICE, WATERHOUSE, PEAT & CO.,
Chartered Accountants,
Auditors.

CALCUTTA,
The 27th September, 1924.

The Institution of Engineers (India).

Income and Expenditure Account for the Year Ending 31st August 1924.

EXPENDITURE.

	Rs	A.	P.	Rs.	A.	P.
To Salaries & Wages				26,601	8	9
,, Postages	546	8	0			
,, Telegrams	26	10	0	573	2	0
,, Printing	1,172	0	0			
,, Stationery	1,333	5	9	2,505	5	9
,, Travelling	3,097	10	0			
,, Conveyances	178	12	0	3,276	6	0
,, Rent .. .	2,810	0	0			
,, Lighting & Fans ..	84	0	6	2,894	0	6
,, Law Charges				68	0	0
,, Journal				4,467	3	0
,, Bulletin				898	11	6
,, Annual General Meeting ..				421	10	0
,, Diplomas .. .				427	7	6
,, Subscriptions to Local Associations				3,742	8	0
,, Audit Fee				250	0	0
,, Charges General ..				1,050	10	3
,, Bad Debts				1,728	12	0
				Rs. 48,905	5	3

INCOME.

	Rs.	A.	P.
By Subscriptions	30,821	7	0
,, Interest	3,250	14	3
,, Sale of Standard Specifications ..	363	10	7
,, Balance, being Deficit transferred to Balance Sheet	14,469	5	5
	Rs. 48,905	5	3

PRESIDENTIAL ADDRESS

BY

H. BURKINSHAW.

President 1925-26.

Gentlemen,—

The Council of this Institution as your representatives have elected me to be your President for the ensuing year, and I wish to express my thanks for the great honour which has been conferred upon me. The honour carries with it a measure of responsibility, and my distinguished predecessors have created a standard to which I shall find it difficult to attain.

Our late President, Mr. C. D. M. Hindley, has been a pillar of strength since the earliest days of the Organising Committee, and it is much to be regretted that he is unable to continue as our President for another year. It is, however, a matter for congratulation that in spite of the many calls upon his services we are to continue to receive the benefit of his invaluable advice and assistance.

The aims and objects for which the Institution was founded are very clearly enumerated in the Memorandum of Association, and those public spirited, selfless Engineers who formed the Organising Committee must find some reward for their labours in the progress which the Institution has made towards the goal they had in view during the 4½ years of its existence. The first eleven paragraphs of Clause 3 of the Memorandum of Association might with propriety be learned by heart and adopted as a creed by all Engineers whether Members of our Institution or not.

The Quarterly Bulletins and the Annual Report give information regarding the Activities of the Institution. It will be seen that these are very far-reaching and fulfil the purpose for which the Institution exists.

The Local Associations, Bengal, Bombay, South India, and the United Provinces are well established and thriving entities. The formation of another Local Association has been mooted and the proposal is receiving the consideration of the Council.

The roll of Membership has increased from a total of 138 in 1920 to over eight hundred to-day, and there is every reason to believe that the number will rapidly increase until every qualified Engineer in India had been enrolled.

A very important decision was made in January of this year in connection with the reduction of the Entrance Fees. The whole question was under consideration for some considerable time, and it was ultimately proposed by the Council and approved by the Members at an Extraordinary General Meeting that the entrance fees should be reduced to Rs. 40 for Members and Rs. 32 for Associate Members. In making their recommendation the Council had before them the considered opinions of many Members and the opinions also of Gentlemen fully qualified to become Members but prevented from doing so by the comparatively heavy initial payments. I would remind Members that moneys accruing to the Institution from Entrance Fees are placed to capital account and are not appropriated to meet revenue expenses. The Institution to-day is not in urgent need of capital nor is it likely to be so for many years to come. It is, however, essential for the well being of the Institution that qualified Engineers should be enabled to join it because then not only will the Institution be strengthened to deal with the purposes for which it exists but it will be strengthened financially and placed in a better position to meet expenditure chargeable to revenue. That the Council's recommendations as approved by the Member has been amply justified is proven by the fact that in the six weeks since the notification of the reduction in Entrance Fees 85 applications for admission to the Institution have been received as against 58 during the whole of the previous twelve months. I particularly wish to emphasise the fact that no alteration whatsoever has been made in the qualifications for admission to the Institution and none except fully qualified Engineers can ever hope to gain corporate Membership.

At no very distant date Membership of our Institution will be regarded throughout India as the hall-mark of the Engineer, and it is our bounden duty to devote earnest attention to the whole subject of the education and training of engineers in India. A number of Colleges and Technical Schools have come into existence, but until our Institution was founded there was no standard of comparison and the parents and guardians of aspiring engineers had none to guide them. Our rules of admission to the Institution together with the entrance examinations have provided a safe and sure standard, and because of this our responsibility is very great. India is at present in a transition stage, it is passing from an almost entirely agricultural country to an industrial country of importance. The growth of Industry and the development of the great mineral resources will necessitate extensions of the Railway systems, and all these will create a demand for trained Engineers. If the progress is to be sure it must be slow, and the rate at which the country can find employment for young engineers is directly proportional to the rate of industrial development. Earnest efforts must be made to ascertain

and to record that rate. Whether this should be undertaken by Government, by the Colleges and Technical Schools, or by this Institution remains to be decided, but it is clearly the duty of this Institution to ensure that engineering students are not being turned out at a greater rate than that at which the engineering resources of the country can provide them with practical training for the completion of their education and later with permanent employment.

It is true and it is deplorable that in Europe and America and possibly also in India there are organisations which in exchange for money will grant high sounding educational degrees and titles. The victims are in certain cases innocent but in many cases the holders have purchased them deliberately with intent to deceive. This Institution will resolutely denounce all such organisations as occasion arises and will steadfastly refuse to recognise all such spurious evidence of education and training.

This year will mark the centenary of the birth of Railways. The Railways are themselves the product of the skill of the three principle branches of engineering --Civil, Mechanical, Electrical---and because this Institution is representative of them all our thoughts naturally turn to the progress which has been made in engineering in general. It is less than 150 years since Watt proudly proclaimed :---"I have now gotten a lathe so true in its work that the bore of the cylinders is nowhere out of truth by greater than the thickness of a sixpence"---to day it is common practice for tolerances of plus or minus half a thousandth part of an inch to be the working limits. The progress which has been made is indeed very great and it has been achieved not by the engineer alone but by the closest co-operation with the Scientist. We owe nearly all to the Physicist, the Chemist, and the Metallurgist, and we can make very little further progress until they give us some new law or material to work upon. It is perhaps not very greatly to our credit that we are still unable to utilise the Latent Heat of Steam in our prime movers and the problem does not appear to be near of solution. From which direction the next great advance will come it is impossible to predict, but whether it comes by the liberation of atomic force, a more direct conversion of heat to electricity, or by some channel not even yet indicated, we must be prepared to receive it, to master it, and to turn it to the useful service of humanity.

I have referred to the close co-operation between the Engineer and the Scientist, and I wish to indicate that there appears to be need for us to confer with the Biologist, more especially with the Bacteriologist with whom we have had few dealings in the past, except in the purification of water and the treatment of sewage. The decay and corrosion of building and other structural materials has been accepted by us as inevitable, we try to prevent it, we succeed in

delaying it, and in somewhat vague terms we blame "chemical action." It is known that many bacteria commonly present in soil and water are able to produce such powerful destructive agents as sulphuric, nitric, acetic, and carbonic acids. These, although formed in small quantities are yet able, by their action over long periods of time, to produce serious effects both upon metals and upon stone or cement.

Soil and water bacteria are also destructive to timber, more especially if imperfectly seasoned, and the by-products of bacterial action upon such lumber are frequently destructive to metals in contact with them. Further instances might be cited among which is the spontaneous combustion of coal. This is probably due to bacterial fermentation and requires investigation with a view to determining the possibility of preventing its occurence by methods based upon recognition of its bacterial origin. In dealing with the problem of the destruction of materials by weathering and decay, more exact information should be obtained as to the underlying causes and the conditions favourable to their action. Such information can only become available as the result of collaboration between the Engineer and the Bacteriologist, which should result in the concerting of measures suitable for the prevention of bacterial action. Our Institution should encourage research in this and kindred subjects, and I look forward to the time when we shall be in the position to undertake such work and to defray the cost from our own funds.

The Civil Engineer has been in India for centuries, the Mechanical Engineer for comparatively few years, and the Electrical Engineer has only just arrived, but the conditions pertaining in India at present are such that the period in which we live may be looked upon as the renascence period of Engineering in India. Our Industries are growing and our Engineering works are cautiously expanding to meet the new needs. The onus for success rests upon the shoulders of Engineers and therefore upon the Members of this Institution, and if we are to progress surely we must standardise. The whole idea of standardization is, broadly speaking, repugnant to the Engineer. His whole attitude of mind is against it due to his training and his inventive instinct, but the price he has paid for experience coupled with his sound fundamental common sense has led him to standardise wherever possible. This Institution is the organisation in India of the British Engineering Standards Association and of the International Electro-technical Commission. These bodies have established standards which have proven good, and they should be adopted by us whenever possible to effect economy and to improve efficiency. The closest and most unselfish co-operation will be needed among Members to establish new standards in India from time to time as circumstances may prove to be expedient.

One of the most important objects of this Institution is to diffuse among its members information affecting Engineering and this can best be achieved by the reading of papers and by discussions upon them. The volumes of the Journal of the Institution contain records of which we are justly proud, and it must be our earnest endeavour to maintain that high standard. The Engineer in India has opportunities which are given to few. Very early in his career he is compelled to take responsibility and to utilise to the utmost the knowledge of the theory and practice of engineering acquired during his training. Although he may be compelled to specialise and to be expert in one particular branch yet throughout his career he must retain a catholic knowledge of engineering in general and keep abreast of the times. The amount of specialised invaluable knowledge in the possession of Members of this Institution is incalculable, and it is of vital importance to the welfare of Engineering in this country that that specialised knowledge should be accessible to the Engineering community. Until this Institution was founded there was no convenient and suitable channel along which information could flow and much knowledge remained as a personal possession or was buried in inaccessible files and office records. The work of the engineer is almost entirely constructive, and it is almost impossible for a description of it to be completely impersonal. In these circumstances, many Members, with a modesty unusual even among Engineers, have expressed their reluctance to become authors of papers because they fear the stigma of self-advertisement. It should not be necessary to re-assure them on this point, and it is greatly to be desired that they will commit their knowledge to paper, so that through the medium of this Institution it may be placed at the service of their fellows and be permanently recorded for the guidance of posterity.

The senior Institutions in England recognising that the Institution of Engineers (India) is representative of the great community of Engineers in this huge country conveyed to us, through the medium of the Kelvin Centenary Committee, an invitation to participate in the celebrations to commemorate the hundredth anniversary of the birth of the great scientist, Lord Kelvin. This signal honour is one of which this Institution is very proud, and that it was my great good fortune to be nominated as your delegate on that occasion is a memory which I shall cherish together with that of the honour which you have conferred upon me to-day in electing me as your President.

THE FIFTH ANNUAL DINNER.

The Fifth Annual Dinner of the Institution was held in Maiden's Hotel, Delhi, on Wednesday, 25th February, 1925.

Mr. H. Burkinshaw, President, presided.

The President proposed the toast "The King Emperor."

The President in proposing the toast "Our Guests," said:

Gentlemen,—

A cynical philosopher has recorded that three things in life are difficult of attainment :—being poor to obtain justice, being rich to escape flattery, and being human to avoid the passions. Our guests to-night are concerned with none of those things, but I would warn them of a fourth which is more than difficult, it is in fact impossible, that is, being civilised to escape the Engineer.

The Hon'ble Sir Charles Innes, who honours us with his presence this evening, is responsible for the great departments of Railways and Commerce. The Railway Budget which our guest has recently presented in such a masterly fashion has given us a glimpse of the magnitude of a portion of his task. What the sum total must be it is impossible for us to hazard, for under the guise of Commerce are such items as the Major Ports, Customs, and the consideration of a Tariff which, whilst producing revenue for the country's needs, shall provide protection for key industries without placing too great a burden upon Commerce.

Railways and Commerce are to a great extent based upon Engineering, and Sir Charles Innes has for many years taken a keen interest in the work of the Engineer in India and has viewed with sympathy the aims and objects of our Institution.

We welcome this opportunity of expressing our appreciation of the interest and sympathy which he has extended to us and we assure him of our loyal support in the great work which he has undertaken.

We extend a most cordial welcome to The Hon'ble Sir Bhupendra Nath Mitra, who is in charge of the important departments of Industries and Labour. With him we associate another most welcome guest, his trusty henchman, Mr. A. H. Ley.

Sir Bhupendra Nath Mitra is a Giant of Finance combining knowledge of his subject with great personality and breadth of vision to such a degree that he not only unravelled the tangled skein of war accounts but also completely captivated Army Head Quarters. We, Engineers, depend for our very existence almost entirely upon the prosperity of Industry and the contentment of Labour. We are satisfied to leave our great interests in their capable hands because we know that they are in safe custody whether it be the duty upon our steel or the duty towards our Labour.

This is the first occasion on which our Annual General Meeting has been held in Delhi, and many of us have seen the new Imperial City for the first time during the last few days. Our admiration has been won by the work of Sir Edwin Lutyens and Mr. H. Baker who planned and designed that magnificent project. It is now under construction by Engineers and will shortly be ready for those who we are sure will be well fitted to occupy it. It is very fitting therefore and very gratifying to us that Mr. Abbott, Chief Commissioner for Delhi, has been able to be present with us this evening. We hold his coming for a happy augury.

It is indeed a pleasure to welcome as our guest General Sir Edwin Atkinson, for he is not only a most distinguished Soldier but also an eminent Engineer. His long connection with the Thomason College, Roorkee, places him as a great authority on the vexed question of the education and training of the Engineer in India. The present successful organisation for Military Supplies in India was devised by our guest, and as Master-General of Supply he is in charge of the Ordnance Factories as well as the supplies of every kind for the Army. General Sir Edwin Atkinson is at once an Engineer, an employer of Engineers, and a user of engineering materials. We hope that when he is wearily scanning those long lists of indents that his labours will be a little lightened by the happy thought that every item is providing a little work for deserving Engineers.

Our welcome to Sir Geoffrey Clarke is tinged with regret because this is the last occasion on which we shall have the pleasure of entertaining him as our guest. He is about to leave India; his work remains as his monument. The Post and Telegraph Service in India has been raised to a state of efficiency that bears comparison with that of any other country. During his long period of office as Director-General of Posts and Telegraphs, Sir Geoffrey Clarke has fearlessly adopted our latest inventions immediately that we have been able to demonstrate that their adoption would be of benefit to the public.

Only too rarely do we find an opportunity of admitting our debt to the Indian Medical Services, and in welcoming Sir Charles Macwatt, we admit that though we have provided X-Rays, Radium, fine steel for instruments, and other aids to their skill, yet these are a small weight in the balance of debt. Those who remember the epidemics of disease in labour settlements 20 years ago and know the conditions of those settlements to-day will realise the magnitude of our debt. The Indian Medical Services conducted many of us safely into the world and enable us all to live in it.

We much regret the unavoidable absence of Sir Peter Clutterbuck, who at the last moment has been prevented from being with us to-night, but we none the less take this occasion to record our appreciation of the services which the Forests Department has rendered and is rendering to Engineers. There is no more useful timber than teak, our paints would be useless without turpentine, we could not have leather belts without tan barks, and our rivers would turn into unmanageable torrents if their catchment areas were denuded of forests.

We, Engineers, are held in check and our enthusiasms thwarted by the certain knowledge that we must ultimately face finance and suffer under audit. Without these cold calculating implacable twins we could accomplish much, there might even be a bridge across the Hooghly. To-night these dread powers are shorn of their terror, and justice is tempered with mercy, because they are represented here to our very great pleasure by Sir Frederic Gauntlett and the Hon'ble Mr. McWatters.

We have one other guest with us to-night for the last time as a guest, on another occasion he will be present as a host, Colonel Hopkins, whose name is one to conjure with in Railway circles, is a member of our craft and is about to become a member of our Institution.

Since the very beginning of the Institution of Engineers, the Press has been very kind to us and once a year we are privileged to offer hospitality to its representatives. Secretly we stand somewhat in awe of the Press because in it we recognise the only dynamic force which cannot be curbed or controlled even by Engineers.

Our hard working and popular Secretary is with us as a guest to-night, and it is with much pleasure that we take this opportunity of expressing our appreciation of the work which he has done for our Institution.

We extend a most hearty welcome to all our guests and we record the honour that their presence confers on us.

It is now my pleasant duty to propose the Toast of our Guests coupled with the name of Sir Charles Innes.

The Hon'ble Sir Charles Innes, in responding to the toast "Our Guests" said :—

"Mr. Burkinshaw and Gentlemen,—I must first thank you on behalf of my fellow guests and myself for this very excellent entertainment and for the very kind way in which you have drunk our health. Mr. Burkinshaw said that this was the first occasion on which the Annual General Meeting has been held in Delhi. My fellow guests and I hope that if only you will ask us again to dinner, the Annual General Meeting will be held every year in Delhi. Mr. Burkinshaw said that it is impossible for a rich man to avoid flattery. I feel that his remark does not apply only to the rich man. I am not a rich man. I am a poor man, but to-night I have not avoided flattery. But I have one complaint against Mr. Burkinshaw. He made a mistake in selecting me to reply to this toast to-night. I have spent the whole day fighting with my back to the wall in the Assembly. My Hon'ble colleague on my left has sat smiling in his seat. Had he been asked to speak to-night, he would have had time to prepare a speech worthy of the occasion. Whereas I am afraid that I shall have to give you just the ideas that come into my head as I speak. At the same time it is a great pleasure to have the opportunity of replying to this toast. I have had a lot to do with engineers in India and have always taken a great interest in engineering. I do not know whether you, Sir, and the others present to-night know the quatrain—written I suspect by a member of the Educational Service—in which engineers and the I. C. S. are coupled together. It runs as follows :—

'The D. P. W. are hardly people to trouble you,

'But I like much less the I. C. S.'

You see, Sir, we are companions in misfortune. It is a fact that like most members of my service, I have come much into contact with engineers and engineering works.

At the very outset of my career in India the great work that engineers had done for India was brought forcibly home to me. My first district was the Madura District in the Madras Presidency—a district which has been transformed by irrigation. Moreover, not long after I joined the district, I was sent on duty to the headworks of the Periyar Irrigation system. I was amazed at what I saw in the middle of the Travancore Hills. It was my first experience of the imagination—I might almost say the impudence—of the engineer. I found a mighty river literally turned back in its course by one of the biggest dams in the world. It had been prevented from following its age-long course to the west coast and had been turned back to convert the arid wastes of the Madura District into smiling fields of paddy. It was in the Madura District too that I

first made the acquaintance of a very distinguished engineer—an engineer who had helped to build the Periyar dam and who in the building thereof had had many strange experiences. That engineer confided to me once that if he had the ordering of his own life he would put himself in charge of an irrigation system. He would like to work out the project himself and would stipulate that he should have all the money he wanted and should not be interfered with. He has not quite realized his ambition, but he has gone very near it. He has been for many years in charge of a great engineering work. he has had ample money to spend, and a fairly free hand. The engineering work is New Delhi and the engineer a prominent member of the Institution who is present here to-night, Sir Hugh Keeling. In my next district, Malabar, the same lesson has been brought home to me. When I was Collector of Malabar in 1911, I came across by chance an old report written by Sir Clements Markham. Sir Clements Markham introduced the cinchona tree into India and in the early sixties he visited the Cinchona Hills, i.e., the Malabar and Nilgiri, Wynaad, to see how the trees were getting on. He wrote an account of his tour in Malabar, Wynaad, and from that account I was able to see in 1911 how greatly that part of his district had advanced in 50 years. Roads had been built and rivers bridged, and it was the work of the engineer that had rendered possible the great development that had taken place in the cultivation of tea and other products. But I believe that the railway engineer has rendered as great a service to India as the irrigation or the civil engineer. It is to the railway engineer that we owe the 38,000 miles of railroad that we now have in India. Of the many distinguished railway engineers I have met, I will mention only two. One is the late Mr. Bell, who was Consulting Engineer for Railways to the Government of India far back in the nineties. His name will always be remembered in connexion with 'Bell's Bunds.' At one period of his career he was engaged in building a big railway bridge in the Punjab. While he was building it, the *Civil and Military Gazette*, Lahore, sent out an officer on its staff to write an article on the bridge. That officer was Mr. Rudyard Kipling, and much of what he had seen appeared many years later in his story 'The Bridge Builders.' Perhaps Mr. Bell was the prototype of Findlayson in that story. The other railway engineer is a distinguished past President of the Institution, Mr. Hindley. I am now working in close contact with Mr. Hindley. Mr. Burkinshaw has mentioned the Railway Budget which I have just introduced. If that Railway Budget shows an improvement in the working of these railways, the credit is largely due to Mr. Hindley.

I must apologise for this frivolous speech; but before sitting down, I should like to steal just a little of General Atkinson's thunder.

I should like to congratulate this Institution on the work which it has set out to do and which it is doing. We are living now in a time of change. I say nothing about the time and pace of that change. But everything is in a state of flux. The change is taking place. The engineering profession will more and more have to depend on itself for the maintenance of its professional standards, and I believe that there is a great future before this Institution. We all know what British Engineering Standards have done for the reputation of British steel. Similarly I hope that Membership and Associate Membership of this Institution will more and more come to be regarded as the hall mark of the engineer in India. I hope and believe that this Institution has a great future before it in the maintenance of standards of engineering training and standards of engineering conduct. I hope, and I am sure that my fellow guests hope, that this Institution will flourish and that as the years go on it will go from strength to strength. I have done. Once more I thank you for your kindly reception of us to-night."

Proposing the toast of the "Institution of Engineers (India)," Major-General Sir Edwin H. de V. Atkinson said :--

There are several reasons, why it is not only an honour but a great personal pleasure to me to propose the toast of the Institution of Engineers (India).

Firstly, as a Royal Engineer I can say not only for myself but for my brother officers how strongly we still feel the bond of union and debt of gratitude due to our civilian step brothers, who came forward so resolutely not only to the help of their country in the Great War, but to the aid of the Corps of Royal Engineers. So through your Institution, I send them this message of regard, gratitude, and thanks.

Then, to the many of the members, I think, I can feel a fatherly feeling as I was for 12 years Principal of the Thomason Engineering College, Roorkee, a position, I only relinquished to go to France. In those long passed days the idea of an institution in India was one of my ideals. It, however, was a hard row to hoe, and I felt that it was only possible by starting local associations in a small way. Turning up old volumes of the Thomasonian I find the first meeting of the Thomason College engineers was held on 8th July 1913 to inaugurate the Association and pass the Rules. I may say that the maximum and minimum yearly subscriptions were modest: Rs. 5/- and Re. 1/-, but to the best of my memory they were hard to collect.

I was then away at the War, and on returning to India in 1921 I was surprised and pleased to find what a fine strong young

Association had sprung up in my absence, whose health I am to have the privilege of proposing.

Now, Gentlemen, there are two points I would like to emphasize. They refer in general to all engineering educational institutions in India, but I may be pardoned, if with my special connections, I especially appeal for the Thomason College, Roorkee.

Those of you who are alumni of that College will know how sincere and honest was my zeal in endeavouring to Indianize the engineer profession in India. But *that* Indianization must be a success, and to be a success Indian students must be trained and turned out up to the highest standard produced in Great Britain. Now, though a few favoured students may succeed in proceeding Home to obtain the best that Britain can give, the majority must get their training in India. It is up to India to give them the best. This can only be done by providing the very best class of tuitional staff, who cannot only impart the highest technical teaching but also those ideals of discipline, *esprit de corps,* and high standards of professional zeal and conduct, which it is the aim of your Association to maintain. I do not for a moment suggest that there are not Indians completely fitted to carry out the above objects, but they are at present not too numerous, and the best are wanted for practical work. In my opinion, to make a success of Indianization, for some time at least, a large portion of the professional staff should be the best Britain can supply. So I appeal to any of you, who have the influence, to see that the politician does not have his way; that he does not say, here are some appointments to fill, our numerous friends want jobs, put them in.

Secondly, Gentlemen, I urge that you should earnestly dig in your toes as to standard. There is a sad tendency in various places to lower standards, to let more men pass. The pre-War standard was high, and I urge on you to combine in every way to insist on the very highest standards being maintained in our engineering colleges.

I have detained you rather long, and now, Gentlemen, this, I believe, is your fifth birthday, and may the wisdom and enthusiasm with which you in such a short time have turned the young child into a stout young man continue till the grave and beneficent grey beard will be looked up to with feelings of thankfulness and reverence not only by the engineering professions but by a grateful India.

Mr. C. D. M. Hindley, in responding to the toast "The Institution" said :—

Mr. President and Gentlemen,—In the name of the Institution of Engineers I have to thank you for the very cordial way in which this

toast has been honoured. I also wish to express our very great appreciation and gratitude to Sir Edwin Atkinson for his kind words regarding the Institution. I have been somewhat unfortunate in my term of office as President of this Institution because in somewhat similar circumstances as are prevailing in Delhi at this moment I was unable to take my proper place at the head of the table at the Annual Dinner last year. I am in the unique position to-night of being the only past President here, and it is therefore my privilege to reply to this toast.

It is very gratifying to have such warm words of appreciation from a distinguished Royal Engineer, whom, I think, I may describe as the representative of the great Corps of Royal Engineers. We on our side are extremely grateful, and indeed we cannot express sufficiently our gratitude for the work which that Corps has done in India and elsewhere, not only from the point of view of the magnitude of the engineering works, which they have carried out, but also for the high standard which they have laid down in India--the standard of professional work and of professional conduct. And here I wish to say how very glad we are that both Sir Charles Innes and Sir Edwin Atkinson have appreciated so clearly the main object of our Institution, the object which rings out clearly throughout our Articles of Association like a trumpet call. The object always in front of us is to establish and maintain high standards of professional work and professional conduct in India. At this moment the Institution of Engineers has before it a vast field. At this moment we have really come into our full heritage because I think I am divulging no secret when I tell you that the Council have before them at the moment applications for membership of such numbers that we can hope at an early date to swell our membership to something like 1,000 members.

Now, Gentlemen, when we reach the figure of a thousand members, which I firmly believe we shall in the course of the next few months, we shall have attained a very definite point in our career. We have achieved what the founders of the Institution were looking forward to possibly in the distant future. That future, Gentlemen, has arrived, and the strength which a large membership gives us is in our hands. There is only one object with which we press forward, and that is based on the firm determination to maintain our standards. In the first place we have to maintain resolutely the standard of qualification for membership of the Institution. Nothing must deter us from maintaining this high standard. Secondly, as General Sir Edwin Atkinson has very clearly indicated we must launch out at an early date on an active policy of maintaining proper standards in the Engineering Colleges

and Institutions of this country. This is going to be no easy task, but I believe the Council has already in hand certain proposals which will work in that direction.

It is perfectly certain that what we have started to do can be achieved if we all put our hands to it. What we want to do is to ensure that the future engineers who are being educated in this country shall come up for membership of this Institution with a proper standard of education. We have laid down certain definite standards for education and for practical training. We shall have our own examinations for the theoretical side and the educational side of the test. We have made certain exemptions from that examination, of degrees and diplomas from certain colleges and institutions. We shall very jealously watch the extension of these exemptions, and we hope by that means, although the task may seem difficult, to influence the standards which the colleges and institutions maintain in their examinations. That, Gentlemen, is the practical policy which the Council have before them and it is up to every one in his own sphere to assist in that policy. Sir Charles Innes has said that the present is the time when such action is essential, when the carrying out of public works is being passed on more and more to Provincial Governments and local authorities. It is up to members of this Institution constantly to place before those authorities the fact that properly qualified engineers are necessary to the proper carrying out of public works. This is the task which individual members can perform probably in a very much more effective way than the Institution as a whole. Individual Members come into contact with local authorities and local Governments and it is up to every one of them constantly to use their influence in that direction.

I think that members will feel that this occasion, when for the first time the Institution has allowed itself to come to Delhi, should be marked by a very definite move forward on the part of the Institution. Possibly members who have visited Delhi from far distant places will carry away with them some idea of the meaning and advantages of a central organization such as exists in the Capital of the Central Government. The Institution itself is based on a federation of local Associations, and as we have always said, the strength of the Institution lies in the local Associations. But it is very essential that members in outlying parts of the country and belonging to the local Associations should realize the necessity for a strong central organization such as is provided by our Council.

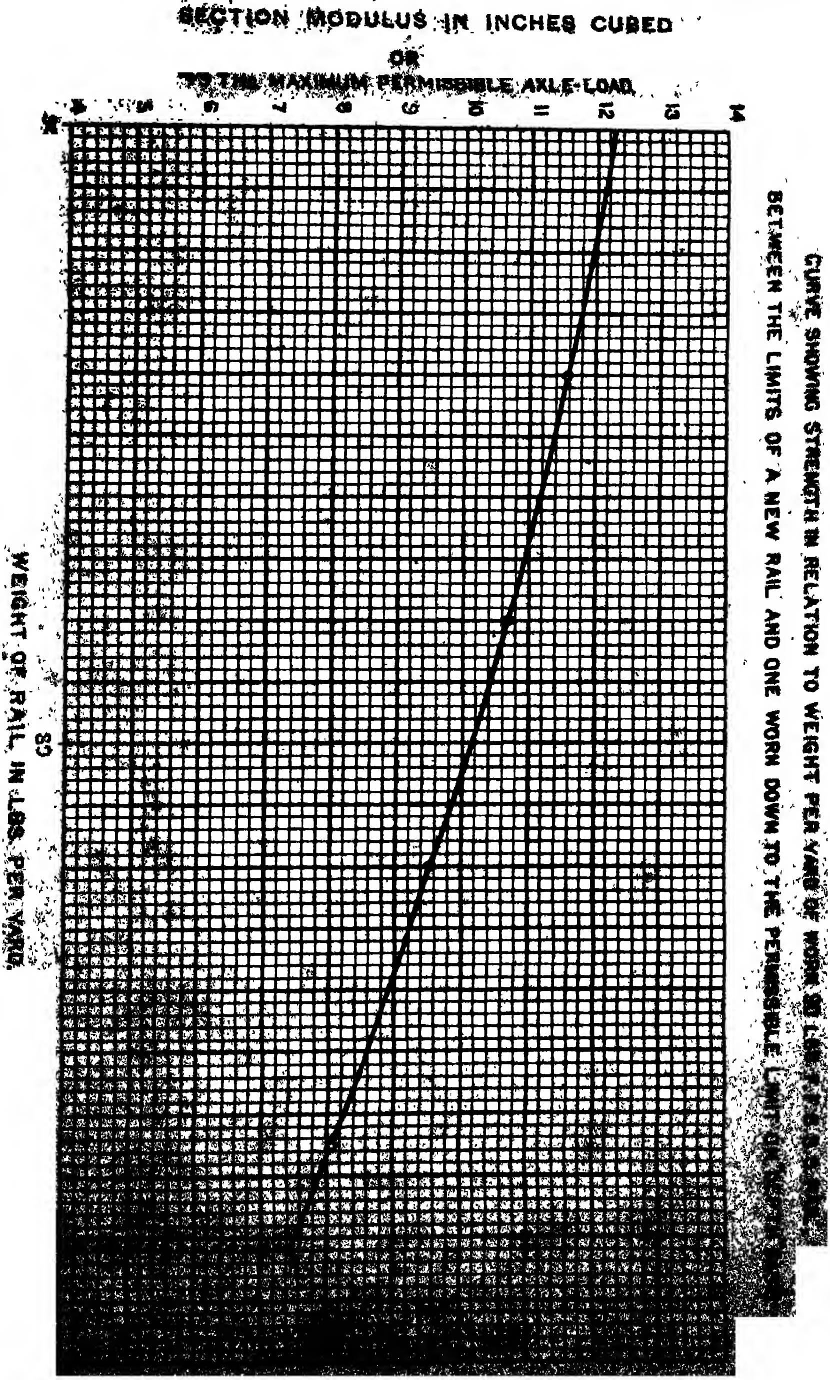
Gentlemen, I am in danger of straying away to the subject of local Associations which Mr. Harris is about to take up. I will

only again thank you for the very kind way in which you have recognized the work of the Institution and the good wishes which you have expressed towards us.

Mr. D. G. Harris proposed the toast "Local Associations."

Mr. R. D. T. Alexander (Bengal), Mr. G. T. Mawson (Bombay), Mr. E. J. B. Greenwood (South India), and Mr. Raja Ram (United Provinces) responded, and gave an account of the work in their respective places. Mr. Greenwood extended an invitation for the Annual General Meeting to be held in Madras, the senior Presidency.

PLATE.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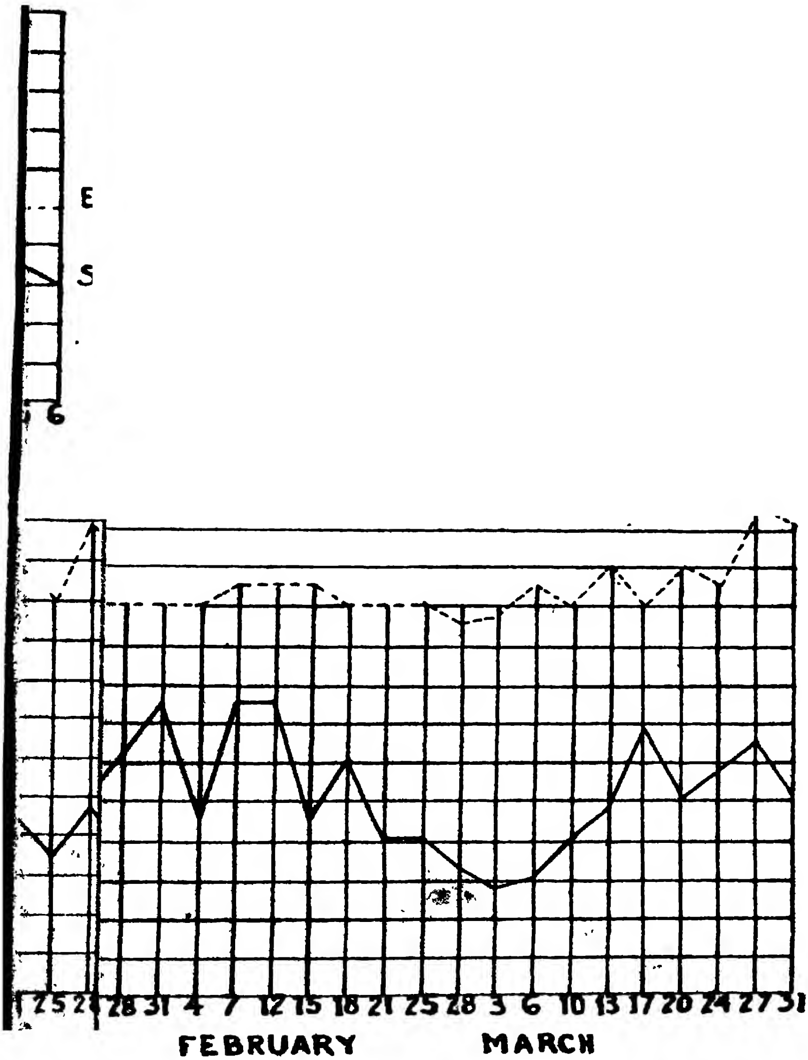


F. C. TEMPLE
&
V. N. SARANGDHAR

THE JOURNAL

OF

The Institution of Engineers (India)

INCORPORATED 1920.

Edited and Published for the Institution by the Secretary.

8, Esplanade Row, East Calcutta.

Vol. VII. DECEMBER. 1927.

CONTENTS:

THE SEVENTH

ANNUAL GENERAL MEETING.

The Seventh Annual General Meeting of the Institution was held in the Seamen's Institute, Ballard Estate, Bombay, at 11 a.m. on Wednesday, 1st December 1926.

PRESENT:

Mr. H. P. Gibbs (in the Chair).
,, W. H. Neilson.
Lieut. Col. G. H. Willis.
Mr. A. C. Coubrough.
,, G. W. Eves.
,, G. E. Bright.
,, Alfred Lines.
,, T. H. Richardson.
,, C. V. Krishnaswami Chetty.
,, E. J. B. Greenwood
Dewan Bahadur K. R. Godbole.
Rao Bahadur S. V. Rajadhyaksha
Mr. N. N. Ayyangar.
,, N. J. Cursetji.
,, E. J. M. Hudson.
,, G. T. Mawson.
51 Corporate Members and Mr. F. Powell Williams (Secretary)

PROCEEDINGS.

Mr. H. P. Gibbs took the Chair at 11 A.M.

The Secretary read the Notice convening the Meeting.

The Minutes of the Sixth Annual General Meeting were read and confirmed.

Item 1.—The Annual Report of the Council and the Statement of Accounts duly certified by the Auditors were handed to all Members present.

It was proposed by Lieut. Col G. H. Willis that the Annual Report of the Council and Audited Accounts be adopted.

This was seconded by Mr. A. C. Coubrough and carried unanimously.

Item 2.—It was proposed by Rai Bahadur Amarnath Nanda that Messrs. Price, Waterhouse, Peat and Co., be re-elected Auditors at a remuneration of Rs. 350 per audit.

This was seconded by Mr. G. W. Eyes and carried unanimously.

Item 3.—It was proposed by Mr. Alfred Lines—

(1) that the following Members of the Institution be re-elected Members of Council:—

Mr. R. D. T. Alexander.
,, N. N. Ayyangar.
,, E. J. B. Greenwood.
,, E. J. M. Hudson.
,, A. H. Johnstone.
,, Lala Jwala Prasad.
,, K. M. Kirkhope.
,, J. McGlashan.
,, W. P. Roberts.
Lieut.-Col. G. H. Willis.

(2) that the following Member elected a Member of Council:—

Mr. Percy Rothera.

This was seconded by Mr. C. V. Krishnaswami Chetty and carried unanimously.

Item 4.—The Chairman reported—

(1) that the Council had unanimously elected Mr. W. H. Neilson as President of the Institution of Engineers (India), for the year 1926-27.

(2) that under Article 9 the following Chairmen of Local Associations are the Vice Presidents of the Institution:

Bengal ... ... Mr. J. McGlashan.
Bombay ... ... ,, N. N. Ayyangar.
United Provinces ... ,, Raj Narain.
South India . Col. H. Cartwright Reid.

(3) that the four past Presidents are:—

Mr. A. C. Coubrough.
Sir Clement Hindley.
Mr. H. Burkinshaw.
Dewan Bahadur A. V. Ramalinga Aiyar.

Item 5.—The Chairman then asked the President to take the Chair and read his Presidential Address.

Item 6.—The President then read his Presidential Address.

ANNUAL REPORT OF THE COUNCIL.

For the year ending 31st August 1926.

The Council have pleasure in presenting to the Members at the Seventh Annual General Meeting their Report of the progress and work of the Institution during the year ended 31st August 1926.

MEMBERSHIP.

The changes in the Membership between the 31st August 1925 and 31st August 1926, are shown in the following table :—

	Honorary Members.	Hon Life Members.	Life Members.	Members.	Life Assoc Members.	Associate Members.	Associates.	Students.	Subscribers.	TOTALS.
Membership on 31st August 1925	3	2	38	303	2	417	5	108	21	899
Addition to 31st August 1926	..	..	..	..	..	..	..	..	..	..
Elected	..	..		27		67	..	32	2	..
Transferred ..	..	..	5	1	2	6	..	..	..	142
Less Deductions :—										
Transferred	..	..	..	5	..	3	.	6	..	..
Deceased	..	..	2	3	..	2	..	1	..	..
Resigned	..	..	..	10	..	7	..	1	..	..
Struck off	..	..	..	1	..	5	1	10	2	59
Membership on 31st August 1926 .. .	3	2	41	312	4	473	4	122	21	982

COUNCIL.

During the year under review certain alterations have taken place in the Constitution of the Council. Mr. A. W. E. Standley resigned on his retirement from India. Lt. Col. Pollard-Lowsley, Messrs. A. A. Biggs and W. S. Fraser resigned on proceeding on

leave. Mr. G. E. Bright was co-opted to fill the vacancy caused by the retirement of Lt. Col. Pollard Lowsley and was subsequently elected a Member of Council at the Sixth Annual General Meeting.

The Council made the following appointments to the Committees of the Council :—

Sir F. Austen Hadow and Mr. H. Burkinshaw to the Papers Committee. Mr. H. Burkinshaw to the Electro Technical Committee. Mr. K. M. Kirkhope and Mr. Alfred Lines to the Applications Committee. Messrs. C. Addams Williams, H. Burkinshaw and T. H. Richardson to the Finance and Administrative Committees. Mr. Alfred Lines was co opted a Member of the B. E. S. A. Committee to act for Sir F. Austen Hadow during the period of his absence on leave.

Mr. J. W. Meares continued to act as the representative of the Council in England.

The Council regret to report the death of Mr. C. L. Cartwright who had been a Member of Council since March 1921.

REGISTERED OFFICE.

The Registered Office of the Institution of Engineers (India) was transferred on the 1st of July 1926, to 8, Esplanade Row, East, Calcutta.

STANDARD SPECIFICATIONS.

The Council continued to act as the Indian Committee of the British Engineering Standards Association and during the period under review received a considerable number of Specifications.

INTERNATIONAL ELECTRO TECHNICAL COMMISSION.

The Council continued to act as the Indian Committee of the International Electro Technical Commission.

The Council were invited to send a representative to the United States of America for the Conference held in April 1926. Owing to no funds being available to meet the consequent expenditure the Council were unable to nominate a representative.

JOURNAL.

Volume VI of the Journal was published early in July 1926, and contained Papers of unusual interest and of great value. The arrangement of the Journal has been altered, so that each Paper is followed by its own plates and by the discussion upon it. Although the bulk of the Journal is less than in previous issues, it

actually contains a greater number of pages and the reduction in bulk has been effected by the adoption of a thinner and more suitable paper for the plates.

BULLETINS.

Bulletins Nos. 10, 11, 12 and 13 were published during the period under review and contained particulars of matters of interest to the Members of the Institution.

ISSUE OF PAPERS.

During the year under review the new procedure sanctioned by the Council for circulating and reading Papers was adopted. Under this procedure, all Papers accepted for reading before the Institution are printed and copies in proof form are sent to all Honorary Life Members, Members, Associate Members, Associates, Students and Subscribers, so that they receive them at least two weeks before the Papers are read at the nearest local centre. The procedure has enabled all connected with the Institution to take an active part in one of the principal objects for which the Institution was formed.

EXAMINATIONS.

No examinations have yet been held. A definite panel of examiners has been arranged, and as soon as sufficient candidates offer themselves for examination, an examination will be held. Of 45 applicants for Corporate Membership who have been informed that they must first pass the Associate Membership Examination, only 3 have applied to sit at the examination.

AWARD OF PRIZES.

H. E. The Viceroy's Prize for the year 1925-26, has not yet been awarded, but it is under the consideration of the Council.

ALTERATION TO ARTICLES.

It has been the custom in the past to hold the Annual General Meeting in February in each year; but this was found to be inconvenient as a great many Members are unable to leave their headquarters during that month. The Institution, therefore, passed a Resolution at an extraordinary General Meeting held on 30th March, 1926, and confirmed at another Meeting held on 16th April 1926, altering the Articles of Association, to enable the Annual General Meeting to be held in November, December or January.

LOCAL ASSOCIATIONS.

During the year the Local Associations have continued to increase in strength and a considerable number of meetings have been held by them. The Council have sanctioned the expansion of the territorial boundaries of each existing Local Association, which when effected will still further increase their strength. The formation of a fifth Local Association which has also been sanctioned by the Council will result in nearly every Member, Associate Member, Associate, Student and Subscriber, being attached to a Local Association.

ACCOUNTS.

The audited accounts for the period ending 31st August, 1926, are appended. The accounts show a deficit on the year's working of Rs. 5,965-9-0.

The considerable increase in the Membership of the Institution together with a marked growth in the activities and work of the Institution have naturally resulted in increased expenditure under many of the items of accounts.

The Council consider that after taking into consideration the great increase in the progress of the Institution's work, the general position is satisfactory.

The Institution of Engineers (India)

Balance Sheet as at 31st August, 1926.

LIABILITIES & SUNDRY CREDIT BALANCES.

	Rs	A	P	Rs	A	P
CAPITAL.—						
Permanent Reserve Account						
Entrance Fees ..	68,329	5	9			
Composition Fees (for Life Membership) ..	11,023	0	0			
Transfer Fees ..	1,248	0	0			
Donations	62,229	10	0	1,42,829	15	9
SUBSCRIPTIONS IN ADVANCE				2,010	1	1
Suspense				37	4	6
LIABILITIES—						
For Expenses	742	4	11			
Bengal Association ..	904	5	0			
Bombay Association ..	1,725	8	0			
U. P. Association	940	6	0			
S. I. Association	687	0	8			
Sundry Creditors	27	14	6	5,026	15	11
B. E. S. A. ALLOWANCE FUND ...				2,687	9	7
NATIONAL ELECTRO-TECHNICAL COMMITTEE FOR INDIA				113	9	8
VICEROY'S PRIZE				500	0	0
IMPERIAL BANK OF INDIA— Overdraft on Revenue Account				4,117	12	5
			Rs.	1,57,323	4	11

ASSETS & SUNDRY DEBIT BALANCES.

	Rs.	A.	P.	Rs.	A	P
FURNITURE & FITTINGS—						
As per last A/c	8,044	8	0			
Additions during the year ..	538	4	0	8,582	12	0
OUTSTANDING SUBSCRIPTIONS				5,171	2	0
SUNDRY DEBTORS				2,914	10	8
DEPOSIT				25	0	0
ADVANCE				842	8	0
STOCK (Stationery)				166	6	3
INVESTMENTS—						
6 10 years Bonds 1930 ..	5,000	0	0			
Ditto 1931 .	42,500	0	0			
Ditto 1932 ..	16,000	0	0	63,500	0	0
CASH—						
AT ALLIANCE BANK OF SIMLA LTD. (in Liqn.)						
On Permanent Reserve A/c	5,351	15	0			
On Donations A/c ..	11,771	1	1			
On Suspense A/c ..	5,298	1	4			
	22,421	1	5			
Less— Recovered ..	12,611	12	8	9,809	4	9
AT IMPERIAL BANK OF INDIA—						
On Permanent Reserve A/c ..	350	11	9			
In hand	164	12	9	515	8	6
INCOME & EXPENDITURE A/c—						
Balance as per last A/c ..	59,830	7	9			
Add—Deficit for the year ..	5,965	9	0	65,796	0	9
				1,57,323	4	11

We have audited the above Balance Sheet with Books of the Institution of Engineers (India), and have obtained all the information and explanations we have required. In our opinion such Balance Sheet is properly drawn up and exhibits a true and correct view of the Institution's affairs according to the best of our information and the explanations given to us and as shewn by the books of the Institution.

PRICE, WATERHOUSE, PEAT & CO
Chartered Accountants,
Auditors

CALCUTTA,
The 28th October, 1926.

The Institution of Engineers (India).

Income and Expenditure Account for the Year Ending 31st August, 1926.

EXPENDITURE.	Rs.	A.	P.	INCOME.	Rs.	A.	P.
To Salaries and Wages	30,823	9	0	By Subscriptions	44,541	4	0
,, Postages	811	14	0	,, Interest	3,799	14	3
,, Telegrams	52	5	0	,, Sale of Standard Specifications ..	334	5	3
,, Printing	631	0	0	,, Balance being deficit transferred to Balance Sheet	5,965	9	0
,, Stationery	1,334	4	1				
,, Travelling	1,298	6	7				
,, Conveyances	103	10	6				
,, Rent	2,760	0	0				
,, Lighting and Fans	72	6	3				
,, Lâw Charges	41	0	0				
,, Journal	4,297	3	2				
,, Bulletins	1,437	13	4				
,, Annual General Meeting	1,103	9	0				
,, Diplomas	81	8	0				
,, Subsidy to Local Associations ..	5,986	0	0				
,, Audit Fee	350	0	0				
,, Charges General	950	0	1				
,, Bad Debts	1,078	0	0				
,, Issue of Papers	1,428	7	6				
Rs.	54,641	0	6	Rs.	54,641	0	6

PRESIDENTIAL ADDRESS.

BY

W. H. NEILSON, O.B.E., V.D.

PRESIDENT, 1926-27.

The position which I find myself in to-day is a consummation of my hopes and ambitions. I deeply appreciate the honour you have shown me in electing me President for the coming year. I may say honestly that, whatever my hopes may have been, I never expected to reach the highest place in the Institution, and with my necessarily incomplete and inaccurate knowledge of my shortcomings, I feel unworthy to tread in the steps of those who have gone before me. You may be certain, however, that I shall do what in me lies to help forward the Institution, and keep its interest to the forefront on all possible occasions.

When the proposal to form this Institution was first put forward, I realised that it would be a most effective means to help Engineers and Engineering in India. I gladly joined the new founded Society and am proud of the fact that I am a founder member. The Institution, since its inception, has achieved a great deal, and with its large and increasing membership, carries great weight in Engineering matters. It has brought together, on a common ground, the men engaged in our profession who are scattered over the vast Continent of India. It has enabled them to exchange ideas, and, what is even better, to get to know each other personally. It has bound us together with a common tie and has undoubtedly raised the status of Engineers in India. We have been able to achieve the latter most important point by insisting on a high standard for election as Corporate member and have further increased our standard by inaugurating a strict examination test when a candidate does not possess sufficient qualifications.

It is said, with the merit of truth, that one receives from an organization much in proportion as one gives to that organization, and I would impress upon members, more particularly our Indian members, for whom the Institution was primarily founded, the necessity, and advantage, of submitting papers, on subjects with which they are most conversant; either to the Local Associations or the parent body. It is not necessary that such papers should deal entirely with original research. Descriptions of works of all

kinds which have been carried out, or are in process of construction, are most valuable, and in many cases impart information to other Engineers which is not available in text-books. The particular difficulties with which one has met, and the method of overcoming them, are not only illuminative but in most cases are highly instructive. One feature which is noticeably absent from nearly all Societies' papers, are descriptions of failures. Naturally one is averse to proclaim one's shortcomings, but it is a fact that more can be learnt from one failure than from a hundred successes. A certain amount of sacrifice from an individual for the benefit of the majority is called for. I am not referring to failures due to faulty construction or design but to those which occur owing to unforeseen or incalculable forces. A good example of what I have in mind is contained in a paper recently submitted by a member on the new entrance to the Kidderpore Docks, where a vivid description is given of the movement of the dock walls in the old docks, shortly after completion. I have no doubt but that the design of the new King George's Dock at Calcutta has been influenced by this extraordinary failure, and the magnificent work, now being carried out under the supervision of Mr. McGlashan, in the neighbourhood of the old docks will surely be carried to a successful conclusion.

Engineers in these days are specialists and perhaps the Port Engineer is one of the most highly specialised products of modern days. The forces he is up against, the tidal currents he has to study, the régime of harbours and Ports which when disturbed cause unenviable anxiety, the dredging problems, the magnitude and depth of the works—all combine to make his position a highly respectable and onerous one. As an Engineer intimately connected with Port and Dock work for over twenty-six years, Members will perhaps pardon me if I turn to this subject which concerns me nearly and in fact concerns India very largely. I refer, in particular, to the Ports of India. Through these ports flow the immense volumes of import and export trade which make up the life of a nation. We have to accommodate in our Ports the ships trading to the British Empire and foreign countries as well as the coastal trade. The gross registered tonnage of shipping entering and leaving Indian ports in 1925-26 was some 65 million tons and the value of the maritime trade approximated Rs. 900 crores. To accommodate this tonnage and give facilities for handling and storing ships' cargoes, as well as erecting and maintaining various entrepots and depots for all sorts and conditions of trade, the Ports of India have spent to date some Rs. 65 crores.

Ports, like other large institutions such as Railways, Municipalities etc., have to keep up to date and it is axiomatic that any

Port which does not do so, must gradually atrophy and become relegated to the back-ground. No Port can afford to stand still, and it is the object of these few remarks to see how we in India are meeting the situation and whether we have proved worthy of our trust.

Amongst the numerous duties which a Port is called upon to do, the chief, and principal one is to provide sufficient and ample accommodation for the ships visiting the Port. It is not difficult or expensive to provide for two dimensions of a vessel, namely, the width and length, but the provision of sufficient depth to keep a vessel afloat at all stages of the tide and to allow her to enter and leave the Port whenever she requires to do so, is a problem which has entailed the expenditure of vast sums of money, and, in the case of some Ports, has placed a limit on the size of vessel which can trade with that particular Port.

We are governed, so far as the draft of boats is concerned, by the available depth of the Suez Canal, and as this depth has been increased from time to time, so Ports have to follow suit. The authorised successive increases in allowable drafts of vessels traversing the canal have been as follows: —

1890	25′ 7″
1902	26′ 3″
1906	27′
1908	28′
1914	29′
1915	30′
1922	31′
1925	32′

The new scheme for improvement drawn up in 1921, provides for a depth of 13 metres or 42′ 8″ and for the transit of ships measuring 15,000 tons gross, length 265 metres, width 29 metres, draft 10·67 metres or 35 ft. The depth of water is made up as follows:—

Draft of ship	35′	useful depth 39′ 5″
Margin between draft of ship and useful depth of canal ...	4′ 5″	
Possible thickness of sand on canal bottom	3′ 3″	
	42′ 8″	

This will allow a draft of 36 ft. if needed.

The increase in depth has been demanded by the ever increasing size of vessels and the following table shows how advantage has been taken of the accommodation provided :—

Number of passages through the canal according to draft and size of vessel.

Draft	1910	1920	1925
Between 26' 3" & 27	174	230	
27 & 28	107	129	
28 & 29		53	172
29 & 30	--	10	44
over 30	- -	---	24
Gross tonnage			
Suez Canal Measurement	1913		
6,000 to 8,000	1238	1246	2178
8,001 to 10,000	334	448	803
10,001 to 12,000	69	96	287
12,001 to 16,000	66	64	101
above 16,000	2	17	70

The Suez Canal has kept well ahead of requirements and there are now only 8 ships afloat which could not pass through at the present authorised draft. These vessels however are high speed passenger boats on the North Atlantic run and it can therefore be said that the Canal can take any vessel afloat on the Eastern Trade. After the completion of the 1921 programme of works, the Canal will be in as good a position to take large vessels as the Panama Canal. The total depth of water in this latter canal is 40 ft. and allowing only the small margin of 3 ft. under the keel, the permissible draft would be 37' but as this is in fresh water the comparable depth in salt water would be about 36 ft.

It is to be seen now how the Indian Ports have met this increase in size and draft of vessels. The larger Ports keep before them the recommendation of the Dominions Royal Commission which stated in their final Report that certain ports on various trade routes should be deepened so that accommodation may be provided throughout these routes for vessels of the following drafts :—

33 ft. on the route from the United Kingdom via the Suez Canal to the East and Australia. Statement A shows the increase in size and draft of vessels trading to Indian Ports.

The greatest draft of any vessel entering Indian Ports (excluding the S. S. "City of Exeter" referred to later) has so far been 33 ft., namely, the "H. T. Caronia" which sailed from Bombay on the 3rd February 1918.

It is now proposed to deal with the various Ports and to state their present and proposed arrangements.

CALCUTTA.

Approaches.

The Port is situated on the River Hooghly and is 82 miles distant from its mouth. Navigation is difficult at the mouth of the river, the channels wind through numerous sand-banks and the best route has to be chosen through ever-varying depths along the line connecting the deep places and over the shallows. These latter vary constantly in depth but when one place gets too shallow, usually another opens out and gives deeper water. Last year the Middleton Bar was the governing bar for 329 days during the year, giving between 15′ 6″ and 16′ 9″. Further up are two shoals, namely, the Balari Bar near the head of the estuary, and the Gabtola Bar. Above these, where the Rupnarain River enters the Hooghly, a seasonal bar is developed. Higher up, there is the famous "James and Mary" reach, caused by the entrance of the Damodar River, where the channel is divided into the Eastern gut and Western gut. Above this, the river has the usual characteristics of Indian rivers in the plains. It wanders about, with the deep channel hugging the concave side, forming shoals at the crossing points. The crossings which give the most trouble are the Moyapur and Royapur. To ensure the best navigational line, a constant system of surveys is kept up together with a complete arrangement of semaphores and river marks. Improvements have been effected on the bars in the upper reaches. The suction dredgers "Sandpiper", "Balari" and "Gunga" work on the Eastern gut and Moyapur Bar where in the case of the former the depths have been increased from 3 to 4 ft. more than was available in the worst months up to 1906 and in the latter an increase of nearly 3 ft. has been obtained. The dredgers also work on the shoal places nearer Calcutta namely Panchpara, Pir Serang, and Sankral. The effect of the work undertaken, in the shape of river surveys and dredging has been to increase the allowable draft of vessels navigating the river from 25′ 2″ in 1880 to 29′- 10″ in 1920. Vessels drawing over 30 ft. can navigate the river by taking advantage of the tides.

Port proper and Docks.

In the Port proper there is plenty of water, the 4 fathom contour being continuous on both sides with the exception of a small patch at the Hastings shoal. Low Spring tides, however, seldom fall below 2 ft. above datum, so this shoal is not a serious one. The depth at the double moorings varies between 30 and 51

feet and at the Strand Road jetties there is an average of 32′—6″ below datum. At the new Riverside jetties, the depth is not less than—34·00 ft. so although these jetties are tidal, there is ample water.

The Kidderpore Docks are entered directly from the River by means of a 60 ft. lock and a single 80 ft. gate. The sill level of both entrances is—17·00 so with a mean neaps rise of 12 ft., there is 29 ft. and on the springs 34 ft. of water, allowing vessels of 28 ft. draft and upwards to enter. Both the Tidal Basin and Docks Nos. 1 and 2 are kept up to a level of +21·50, and the bottom of the Docks being 12·00, there is 33½ ft. of water in the Docks. The designed water level was + 16·00 but this was raised owing to the failure of the walls shortly after construction.

The 80 ft. entrance however has never been much used chiefly on account of the high level of the water in the Docks and also because it is at right angles to the river. Consequently all the work fell on the 60 ft. lock. This lock is only 400 ft. long between gates but with the use of caissons at both ends vessels of 510 ft. in length can use it. With the increasing size in vessels and as the lock has been used without cessation, the necessity of building a larger lock arose, and this is now in course of construction. The new lock, which is close up against the old one, has a width of 80 ft. and a length between gates of 580 ft. By means of caissons another 80 ft. can be added to the length. The level of the outer sill is 19·00 and of the inner sill-17·00.

In addition to this, a new Dock system, which will eventually contain over 30 berths, has been designed and work commenced on five berths and two entrances. The situation of this Dock is about a mile below the Kidderpore Docks. The entrances are duplicated, one of them being designed as a tandem Dry Dock. The entrance lock, closed by sliding caissons, has a length of 700 ft. and a width of 90 ft. with the inner sill at 21·00 and the outer sill at -22·00. The minimum drafts in the lock are 31 ft. at High Water and 24½ ft. at Low Water. The tandem dry dock has a width of 80 ft. and a total length between centres of caissons of 1,216 ft. divided into two clear lengths of 590 ft. and 575 ft., the inner and outer sill levels being both at -21·00. The water in the Dock will be kept at + 15·00.

BOMBAY.

Port Approaches.

The distance from the Pilot Station to the anchoring ground is some 4½ miles and the depth of the channel varies from 40 ft. to 33 ft. below L. O. S. T. The anchoring ground for large vessels

has a depth of 10 ft. and these vessels can swing at their anchors in this area.

Port Proper and Docks.

The approach channel to the older Docks has a depth of 17 ft. and to the Alexandra Dock 24 ft. This latter is now being dredged to 28·00. The datum is that of lowest ordinary spring tides but as L. W. O. S. T. is 2 ft. 3 ins. higher, this additional depth can be secured on most days of the year. The Ballard Pier, at which the mail steamers berth, has a depth alongside of 28 ft. and is now being deepened to 32 ft. below L. O. S. T.

The Prince's and Victoria Docks, opened respectively in 1880 and 1888, have single gate entrances and are consequently half tide docks. The sill level of Prince's Dock is 11·00 and that of Victoria Dock, 16·00. The water level of both Docks is kept at about + 8·00 and the bottom levels being 17·00 and 19·00, there is an available depth in Prince's Dock of 25 ft. and in the Victoria Dock 27 ft. The length of vessels having outgrown the original designed length of berth, the number of berths in Prince's Dock is now 9 as against 11 in 1883 and in the Victoria Dock the number has been reduced from 16 to 13. This shows the advantage of straight line berths.

The Alexandra Dock opened in 1913, has an entrance lock 750 ft. long between gates and 100 ft. wide. The length can be increased by the use of caissons. The level of the outer sill is 27·00 and the inner sill 23·00 The level of the bottom of the Dock is 25·00, and with the water in the Dock at an average level + 11·00, there is available 34 ft. of water over the inner sill. On High Water Springs this can be increased to 37 ft.

The Hughes Dry Dock, 1,000 ft. long, is entered from the Alexandra Dock and has a width of 100 ft. at the entrance and a sill level of 22·00. The Dock therefore is capable of ordinarily taking vessels drawing 32 ft., but ships of deeper draft can be docked when required. In June 1917, the *City of Exeter*, having struck a mine outside the Harbour, was drydocked with a draft forward of 34 ft. 4 ins. and aft 22 ft. 5 ins.

At the north of the Harbour is placed a bulk oil pier for kerosene and petrol and has an approach channel dredged to - 20·00 with 30·00 at the turning and swinging basin and alongside the Pier, which is in tidal waters.

KARACHI.

Port Approaches.

Karachi is a tidal Port with an approach channel about 2 miles long to the jetties and about a cable in breadth. The depth of this

channel is at present about 25 feet below L.W.O.S.T., but arrangements are being made to deepen this to 28·00 as well as the channel abreast the jetties. The mouth of the Harbour, which formerly had a bar with only 8 ft. of water, is controlled by a training groyne on the east side and a breakwater on the west side which effectively maintain a permanent depth at the entrance of 27 ft.

The mean range of greatest ordinary spring tides is 9 ft. 3 ins., but as there are several minus tides, varying from a few inches to a foot, during the year, the available depths are somewhat diminished.

Port Proper.

The depth of water at jetties, some of them built many years ago, varies from 27 to 29 ft. at L.W.O.S.T. The west wharf now under construction is of monolith design and these berths will be dredged to 31·00. This depth together with the proposed increased depths in the channel and entrances will allow a 33 ft. draft vessel to enter at H.W.O.N.T., with 5 ft. under the keel at the entrance, 2 ft. under the keel in the channel and 1 ft. when lying alongside.

Further proposals are in hand for re building the jetties on the eastern side so as to give a greater depth at Low Water.

The Harbour is really a large lagoon capable of practically ed expansion. The waters from the Chinna Creek, an inland basin, flush the ships' channel every tide and help to keep this to the depths required. The jetties and west wharf being built in straight lines can adapt themselves without alteration to the longer vessels visiting the Port and the width between these wharves being 1,200 ft., there is ample room to swing a vessel preparatory to berthing or leaving the Port.

RANGOON.

Port Approaches.

Rangoon, the Port of Burmah, handles the whole of the import trade and a very large proportion of the export trade. The Port is a tidal one, the mean range of greatest ordinary springs being 16·4 ft. Indian Spring Low water mark is + 1·56 ft. There are a few minus tides in the dry weather varying to 7 inches. The distance from the Pilot Station to Elephant Point at the entrance of the Rangoon River is about 18 miles and from there to Rangoon 22 miles. The Rangoon River is the name given to the lower reaches of the Hlaing River which is one of the mouths of the Irrawaddy, and the approach to the river entrance is divided by the

Eastern Sands. The Eastern channel is at present not used but shows signs of opening out, while the west channel, at present navigated, shows from recent surveys that the least water on the bar remains at 15 ft. From there there is good water all the way up to Liffey Island reach where there is a 20 ft. shoal. Liffey Island is the crest of a shoal known as the Hastings which is situated at the confluence of the Rangoon and Pegu Rivers and constitutes the principal obstruction to navigation. The Hastings carries from 5 ft. to 12 ft. according to season, but a dredged channel round its edge along the left bank of the river, known as the Monkey Point channel, is maintained between 15 and 16 ft. In 1866 the width of the Rangoon river between Monkey Point and King's Bank was 6,950 ft., but owing to erosion at King's Bank the width in 1922 had increased to 9,650 ft. In 1922 the Commissioners sanctioned a scheme for the erection of a brushwood and stone groyne 6,000 ft. in length at the King's Bank. This groyne is being erected on approximately the line of the 1866 foreshore and the idea is to hold the Rangoon River to a definite width of 6,950 ft. and protect the King's Bank foreshore and also to improve the water in the Monkey Point channel which will equalise the navigable depth on the inner and outer Bars.

Port Proper.

The Port proper comprises the east and west reach of the Rangoon River just above that River's confluence with the Pegu River and extends for about two miles and is from ¼ mile to ½ mile in width. An extensive training wall at the west limit of the Port where the river takes a sharp turn north has saved the left Bank of the river within the Port from silting and has effectively prevented or reduced erosion on the right side. Along the Rangoon side are a number of pile jetties and pontoon landing stages, the length of wharves being 2,822 ft. with 25 ft. depth alongside. These wharves will be extended to form a continuous line of 4,000 ft. including a berth to accommodate vessels drawing 30 ft. There are a number of fixed and swinging moorings both in the Harbour, the Pegu River, at Kemmendine and below Hastings, with 45 ft. to 25 ft. at low water. These are being increased in number.

Nearly all loading is done in the stream and very deep ships have to go below Hastings to complete before departure or lighten before going up to Rangoon. Oil tankers fill up at Syriam, below Hastings. The Port Commissioners have purchased and leased a large area of land with a frontage on the Pegu River with a view to building enclosed docks should it be found necessary to do so. The position chosen will avoid the necessity for vessels having to navigate the Monkey Point channel and will thereby improve the turn-round of deep draft vessels.

MADRAS.

Madras, formerly an open roadstead, has now a well sheltered harbour of 200 acres. Alterations have taken place from time to time in the Harbour, the entrance has been moved from the East to the North and deep water quays have been constructed in place of open piers and fixed moorings. Situated on the Bay of Bengal, the range of spring is small, namely 3·5 ft.; mean L. W. O. S. T. being 1·76 ft. above Datum of soundings. The width at entrance is 400 ft. with 34 ft. depth at low water. The new west quay has depths of $27\frac{1}{2}$ to $31\frac{3}{4}$ ft. and it is proposed to deepen quays Nos. 2 and 3 to $33\frac{3}{4}$ ft. The south quay will also be deepened from $31\frac{3}{4}$ ft. to $33\frac{3}{4}$ ft. and the north quay under construction will have a depth alongside of $33\frac{3}{4}$ ft. The east and outer quays are at 27·76 and the petrol jetty (outside the Harbour) will take down to $32\frac{3}{4}$ ft. from $32\frac{1}{4}$ ft. The buoy moorings at present between 30 to $32\frac{1}{2}$ ft. will all be dredged to $33\frac{3}{4}$.

VIZAGAPATAM.

Port Approaches.

This is a port in the making and will be the only Railway controlled port in India. The natural features are somewhat akin to those of Karachi. The Port is a tidal one, the greatest range of ordinary spring tides being 5·1 ft. Datum is Indian Spring Low Water mark, but there are several minus tides during the dry weather varying from a few inches to a foot. The highest recorded High Water was 6·70 ft. The distance from the 5 fathom contour in the Bay to the Harbour is under $1\frac{1}{2}$ miles and the consideration of the construction of the breakwaters is deferred until it can be decided whether it is less costly to keep the channel open by maintenance dredging rather than construct such breakwaters. There is little lateral movement of sand at the entrance and tidal currents are practically normal to the shore. The channel in the creek has rock to the south side and north side will be protected with stone pitching. Both channel and Harbour proper are to be dredged to—30·00 and the dredgings used for reclamation.

Harbour Proper.

The complete scheme for the Harbour consists of a series of parallel jetties in echelon varying from 3,781 ft. long to 2,150 ft. and width from 650 ft. to 550 ft. The distance between jetties will be 500 ft. to 600 ft. The first section of works includes a wharf wall 1,800 ft. long berthing three ships. Moorings for two vessels will be laid down and an oil depôt on the south side of the Harbour with a mooring for one ship will be constructed as well as a wharf for manganese ore. The channel opposite the oil tanks will be taken

down to 20·00 and a tidal scour channel joining up the tidal scour basins to the Harbour will be taken out to -1·00.

CHITTAGONG.

Port Approaches.

This port affords a good example of the difficulty of dealing with Indian rivers. Above Sadar Ghat, the river has sometimes cut into the bank a distance of 100 feet in one year, making a channel 40 feet deep at low water where there formerly were rice fields. It has also, in one freshet, short-circuited a long bend and altered the position of the main channel by nearly half a mile. The effect of such heavy erosion is felt on the Inner Bar which silts up about 4 feet in a few days. Below Sadar Ghat the concave bank has been revetted with stone on the "Bell Bund" principle.

The approach to the jetties is 9 miles long with an Outer and Inner Bar with 10 to 12 feet of water at low tide and a sharp turn at the Gupta Crossing which carries about 11 ft. Between the jetties and Sadar Ghat, near which the coasting vessels swing, is the Ring Bar with 15 feet, partially dredged through to 21 ft.

Dredging is carried on continuously on the Inner and Outer Bars, in order to keep these Bars open as much as possible.

Port Proper.

The Port is a tidal one, springs rising to 13 feet in the dry weather and 16 feet in the rains Minus tides fall to as much as 18 inches below datum of soundings, the day tides being higher between March and September, and lower between September and March.

There are four jetties with a depth alongside of 24 ft. as well as double and single moorings with depths of 21 to 25 ft. and an oil berth further down the river with 28 ft.

The Port Authorities are about to undertake a comprehensive scheme for the improvement of the entrance to the Port. The mouth of the river is bifurcated and the flood comes up the Juldia channel when the last of the ebb is traversing the Patunga channel. The latter is the one used by vessels entering and leaving the Port. The proposal is to close the Juldia channel at its upper end thereby throwing the ebb and flood streams in one channel. This work, together with dredging the stiff plastic clay, of which the Inner Bar is composed below – 14·00, should have the effect of doing away with both the Inner and Outer Bar. In addition, further revetting will be done on the Patunga side so as to hold the bank where the main stream impinges on it.

OKHA.

This Port is one of the latest to be developed along conventional lines.

Situated in the Gulf of Cutch behind Dwarka on the Arabian Sea it is almost land-locked, the entrance being protected by Samiani Island and numerous sand banks. There are two approach channels to the East and West of Samiani Island with a depth of 18 and 22 ft. at L. W. The Port itself is tidal, the mean range of greatest ordinary springs being 12·4 ft. Datum of soundings is M. L. W. O. S. T., there being a few minus tides of two or three inches.

One pier has been built 400 ft. long connected with the main land by a viaduct 500 ft. long. It can berth two vessel one on either side.

The depth of of water alongside the Pier is 30 ft. at low tide and vessels can anchor off the Pier in 24 ft. of water.

COCHIN.

Developments are now taking place for the purpose of providing Cochin with a first class Harbour. The Harbour will be a tidal one, the mean range of greatest ordinary springs being 3·2 ft. Datum of soundings is --M. L. W. O. S. T. and the Highest High Water recorded is +4·30. There are a few minus tides during the year, but these are of no importance.

The first stage of the work which is now being carried out is the dredging of the Harbour and its approaches to allow vessels drawing 26 ft. to moor in the stream. The area near by is being reclaimed from the dredging. The foreshore on the north side of the Harbour at Vypeen has been protected and portion of the reclamation wall completed. The channel through the outer Bar has been dredged and in order to keep the ebb and flow of tidal water in the required direction, a channel in the back waters, 6,000 ft. by 100 ft. wide and 18 feet deep, has been made.

The new channel, near the crest of the Bar, will be 800 ft. wide and the depth 35 ft. at low water

The whole scheme contemplates the provision of wharves or jetties with complete modern equipment and the extension of railways to serve the Port.

TUTICORIN.

Similar developments to those taking place at Cochin are being carried out at Tuticorin. The tide levels are the same as those at Cochin with the exception that there are no minus tides, low water

springs being +0·30. There are certain peculiar tides at the time of the Moon's quarters when there is no true high or low water, with practically slack water during the tide.

It is proposed to form a turning basin for vessels drawing up to 26 ft. and later on to construct wharves or jetties with mechanical equipment and railway service. At present dredging and rock breaking is being carried out and a narrow land-locked canal with a turning basin of 1,000 ft. square is being made.

The hard material will be dumped on the site of the breakwaters which take the shape of two converging arms for the protection of the approach channel.

A protection embankment to the south-west of the Harbour will be thrown up to prevent blown sand entering the Harbour.

MORMUGAO.

The Port of Mormugao is in Portuguese territory about 225 miles south of Bombay and was acquired by the Portuguese in 1513. It is directly on the Arabian Sea and the Harbour is protected by a breakwater 1,700 ft. long and a mole, 900 ft. long, runs from the end of it. The accommodation is tidal, spring tides being about 6 ft. The depth at the entrance is 27 ft. at low water and the area of the anchorage 99 acres, with a depth from 23 to 26 ft. A drag suction hopper dredger is used to remove the siltation which occurs during the monsoon months. The quay wall is 2,000 ft. long with 5 berths. At the first three there is a depth alongside of 24 ft. and 30 ft. at the others. The new extension is designed for 30 ft. at low water.

From the above, necessarily brief, resume, it will be seen what the Ports of India (the Port of Colombo is not considered in this review) are doing to meet the situation caused by the increase in size and draft of modern vessels. All the major ports in the course of a few years will be well ahead of the times. River Ports such as Calcutta and Rangoon are handicapped by long approaches and difficult navigation and the expenditure to improve these approaches must necessarily be heavy.

India with its vast coast line of over 1,500 miles has few major Ports and the addition of a new one at Vizagapatam will naturally tend to help the maritime trade and afford another outlet for the great export trade of India. The minor and coast ports are also taking themselves seriously and are improving their harbours so as to get their share of the trade.

There are other matters also which must be considered in connection with facilities offered for large vessels but space precludes. Two items which are important may be mentioned, namely, bunkering facilities for motor vessels and those using liquid fuel and

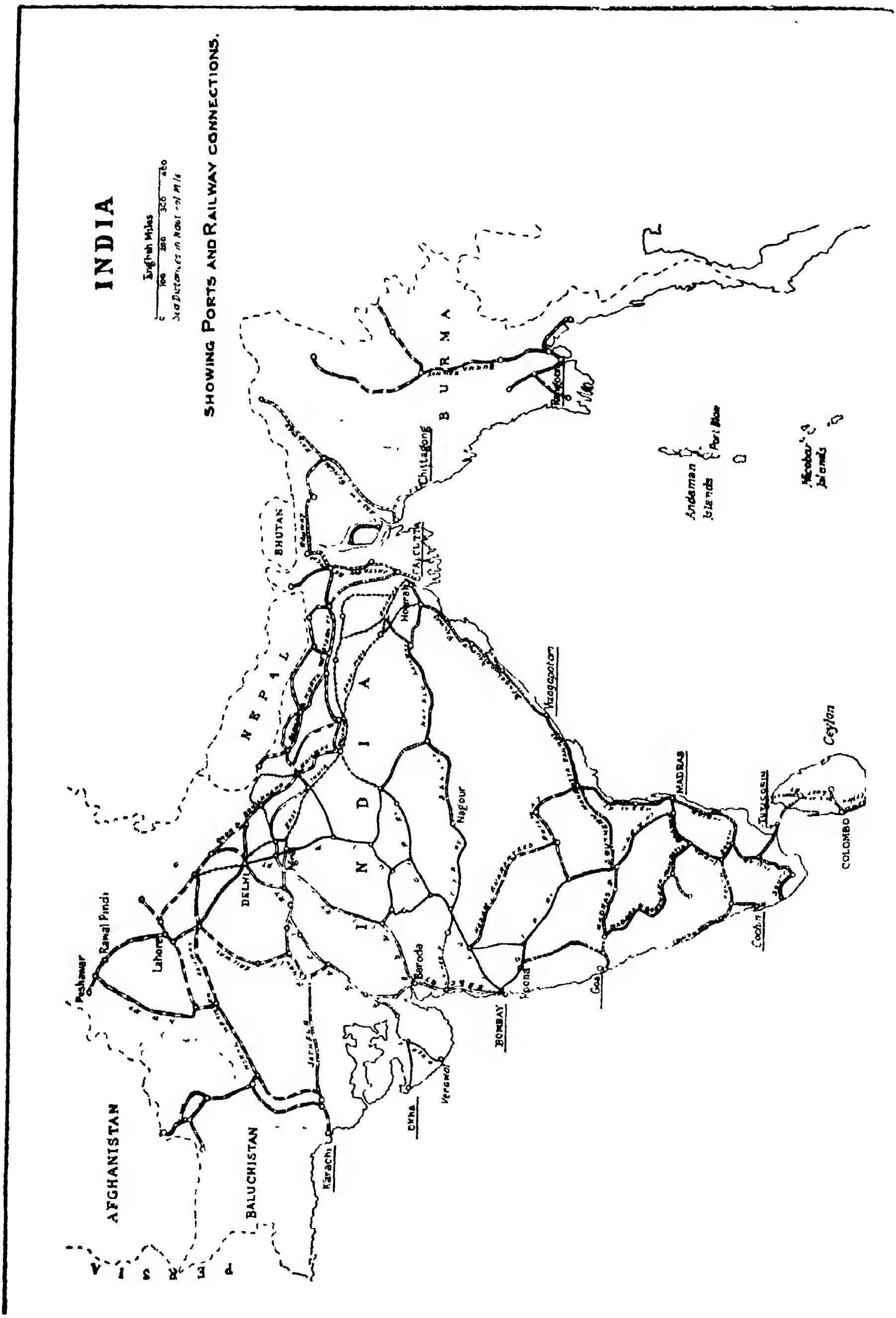
also Dry Docks. Most of the major ports can now bunker such vessels at any berth they are likely to go to and further extensions of pipe lines and connections are in hand. As regards Dry Docks India is rather poorly supplied. Bombay has a 1,000 ft. graving Dock and Calcutta is now completing an even larger dock but beyond these two there are no others which can take the big vessel. This situation will undoubtedly be remedied in the course of the next decade.

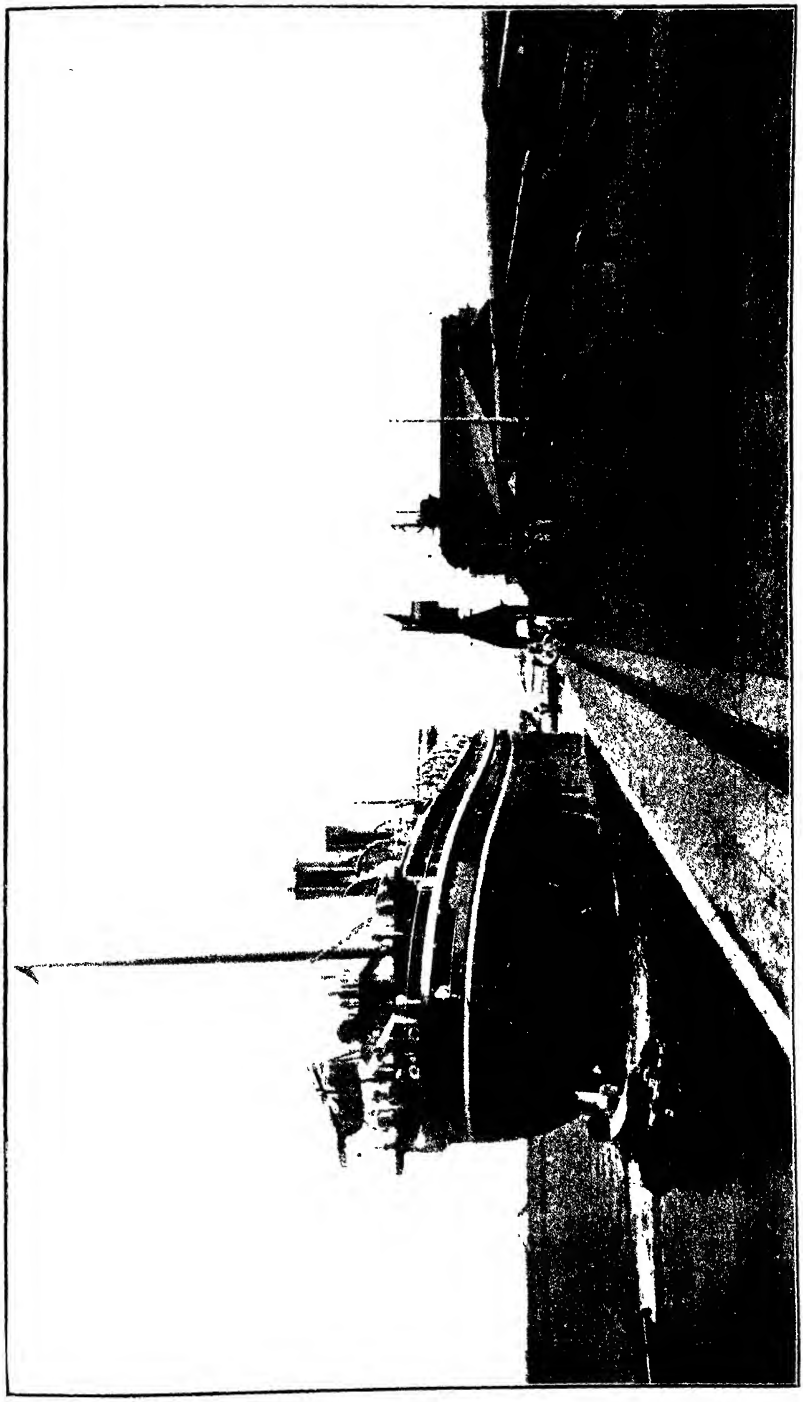
The standard of 33 ft. draft mentioned previously is gradually being worked up to, but the advent of the motor boat has no doubt affected this standard and it is probable that the figure of 33 ft. will not be reached for some considerable time. A motor ship on an extended voyage can, with a somewhat smaller tonnage, carry some 25 per cent. more cargo than a coal-burning steamer. In addition to this, the motor ship has a lower operating cost and these factors will cause more motor ships to be constructed than steamers so that in the near future the former will carry the bulk of the ocean trade. Sixteen years ago the motor vessel was practically unknown and if its advent will prevent, anyhow for some time, the steady increase in draft of vessels, then Port authorities will owe them a debt of gratitude.

I have to acknowledge with thanks the ready help given to me by the various Port authorities in preparing these notes.

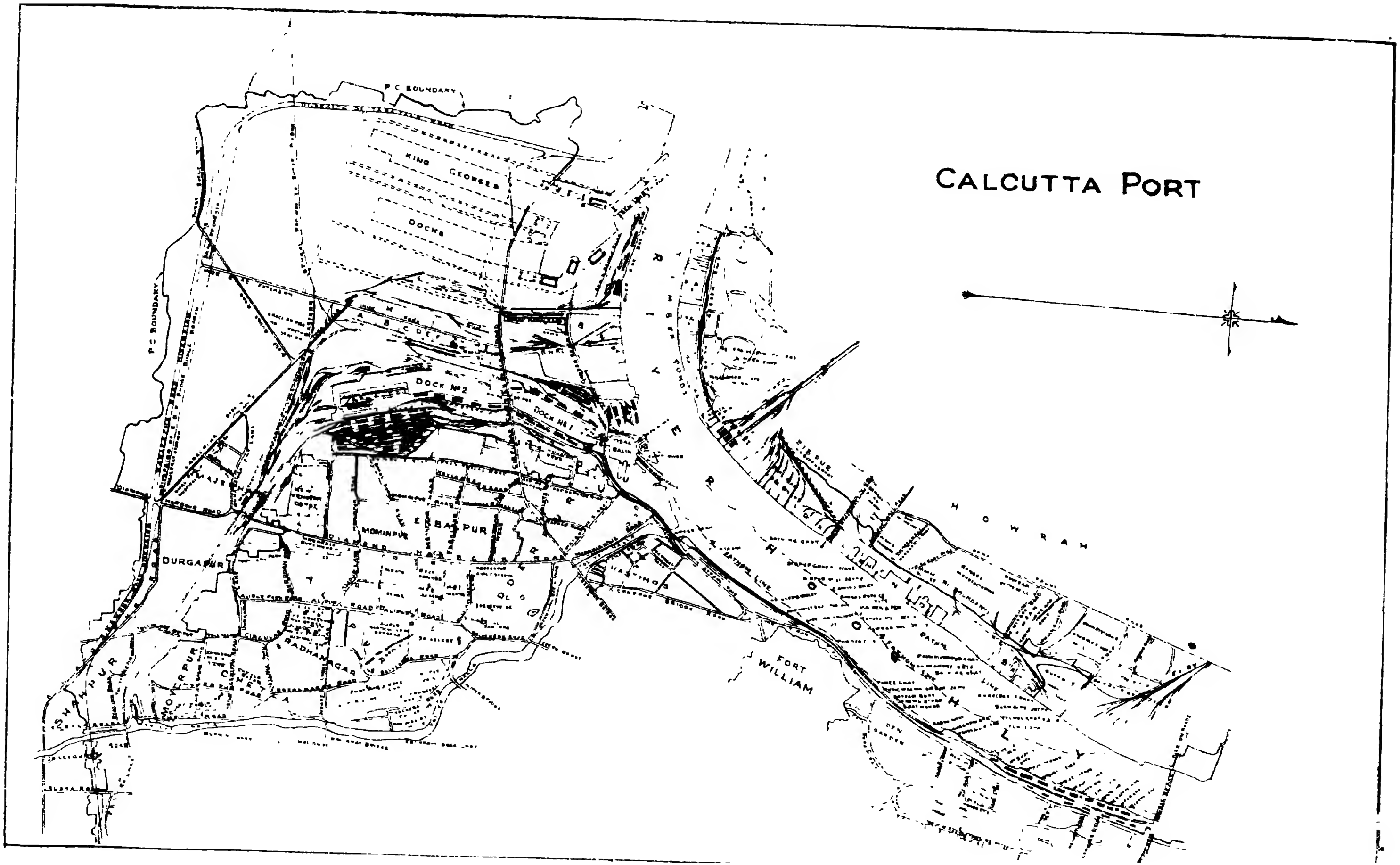
STATEMENT SHOWING INCREASES IN DRAFT AND SIZE OF VESSELS CALLING AT INDIAN PORTS.

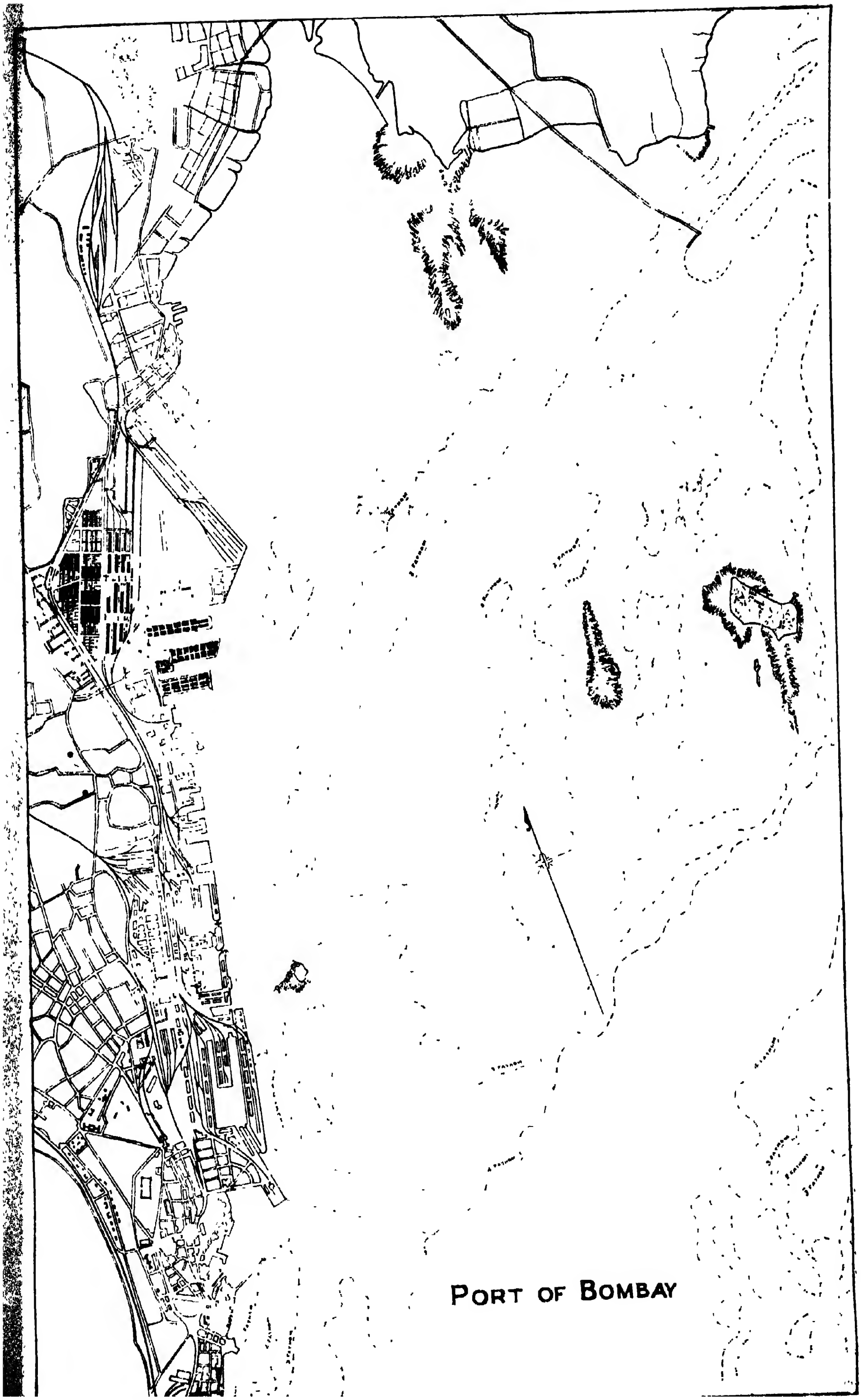
	1910.					1920.					1925.				
DRAFT.	Calcutta.	Bombay.	Karachi.	Rangoon	Madras.	Calcutta.	Bombay.	Karachi	Rangoon.	Madras.	Calcutta.	Bombay.	Karachi	Rangoon.	Madras.
At 25′ and over	227	96	58	124		225	160	41	119	38	196	122	41	215	99
26′ ,, ...	100	48	31	119		196	104	25	147	14	178	101	37	145	43
27′ ,, ...	29	20	9	68		59	43	11	31	5	68	59	20	78	15
28′ ,, ...	6	5	5	29		23	42	14	29	3	41	30	15	63	8
29′ ,, . ..	..	3	..	12		2	4	1	35	4	3	10	5	25	2
30′ ,, . ..	..	..	..	..		..	3	..	4	..	3	3	..	6	..
31′ ,, ...	..	..	..	..		..	..	..	..	..	..	1	..	1	..
GROSS REGISTERED TONNAGE															
6,000 to 8,000	98	139	45	56	79	176	204	88	99	148	247	264	111	152	208
8,001 to 10,000	5	19	2	5	2	33	91	29	20	12	75	70	27	51	61
10,001 to 12,000	..	7	..	.	..	4	21	..	2	..	5	34	5	9	1
12,001 to 16,000 ..	..	..	..	..	..	..	11	1	..	..	.	3	..	..	..
Over 16,000	..	1	..	1	..	..	10	..	..	..	.	23	..	..	..

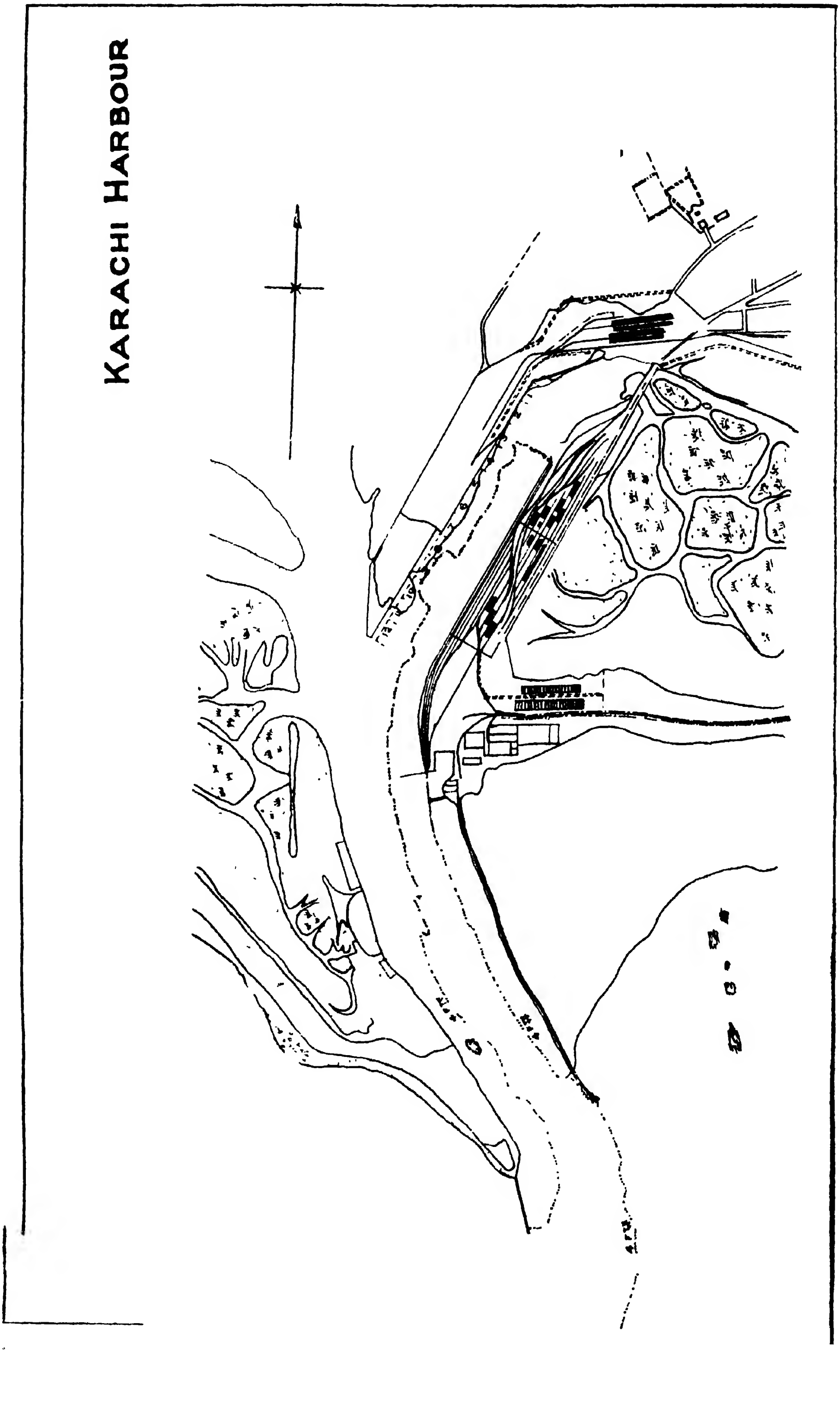

INDIA
English Miles
SHOWING PORTS AND RAILWAY CONNECTIONS.
AFGHANISTAN
BALUCHISTAN
PERSIA
NEPAL
BHUTAN
BURMA
Peshawar
Rawal Pindi
Lahore
DELHI
Karachi
Okha
Veraval
Baroda
BOMBAY
Poona
Goa
Cochin
Nagpur
Vizagapatam
MADRAS
TUTICORIN
COLOMBO
Ceylon
Howrah
CALCUTTA
Chittagong
Rangoon
Andaman Islands
Port Blair
Nicobar Islands

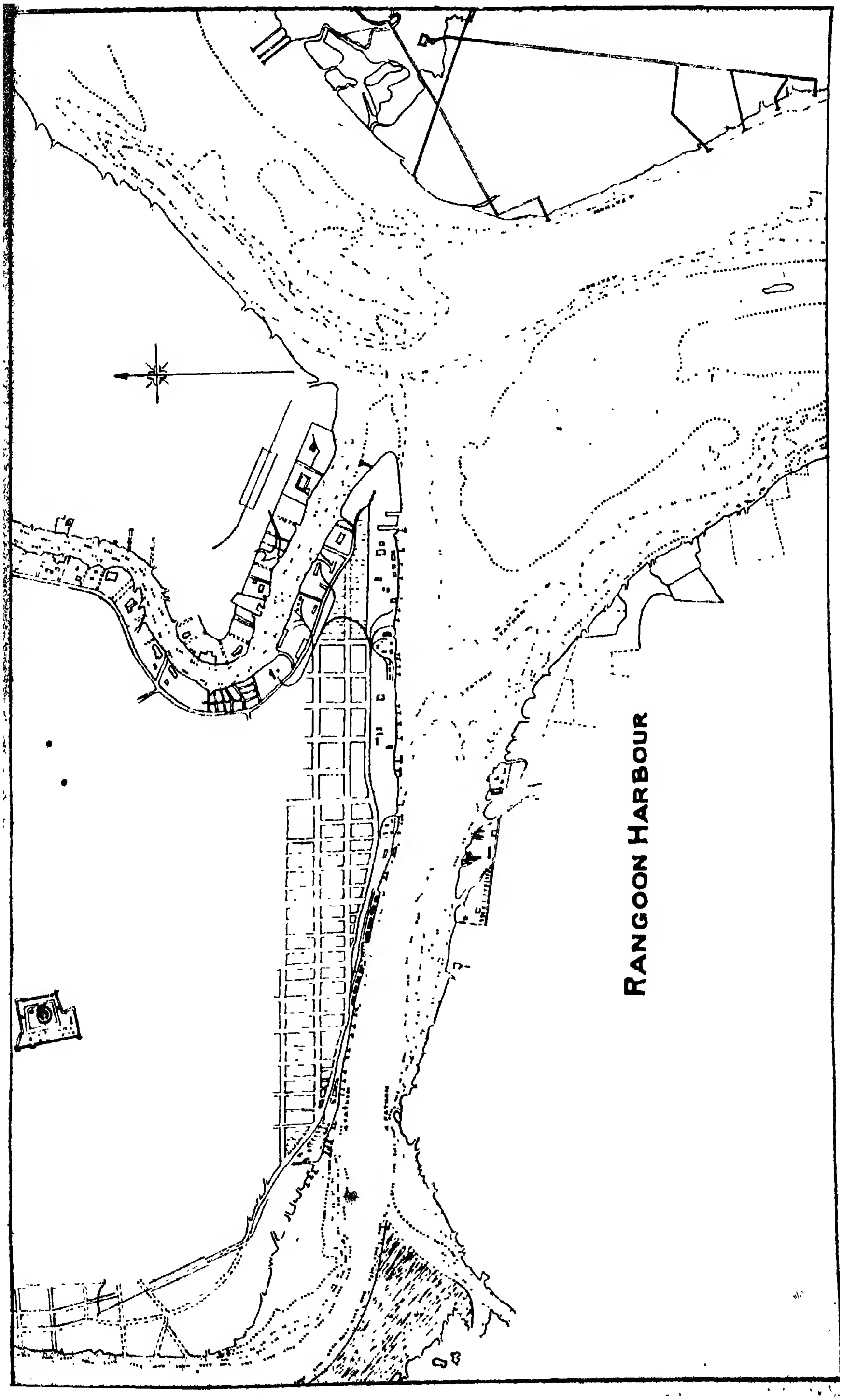


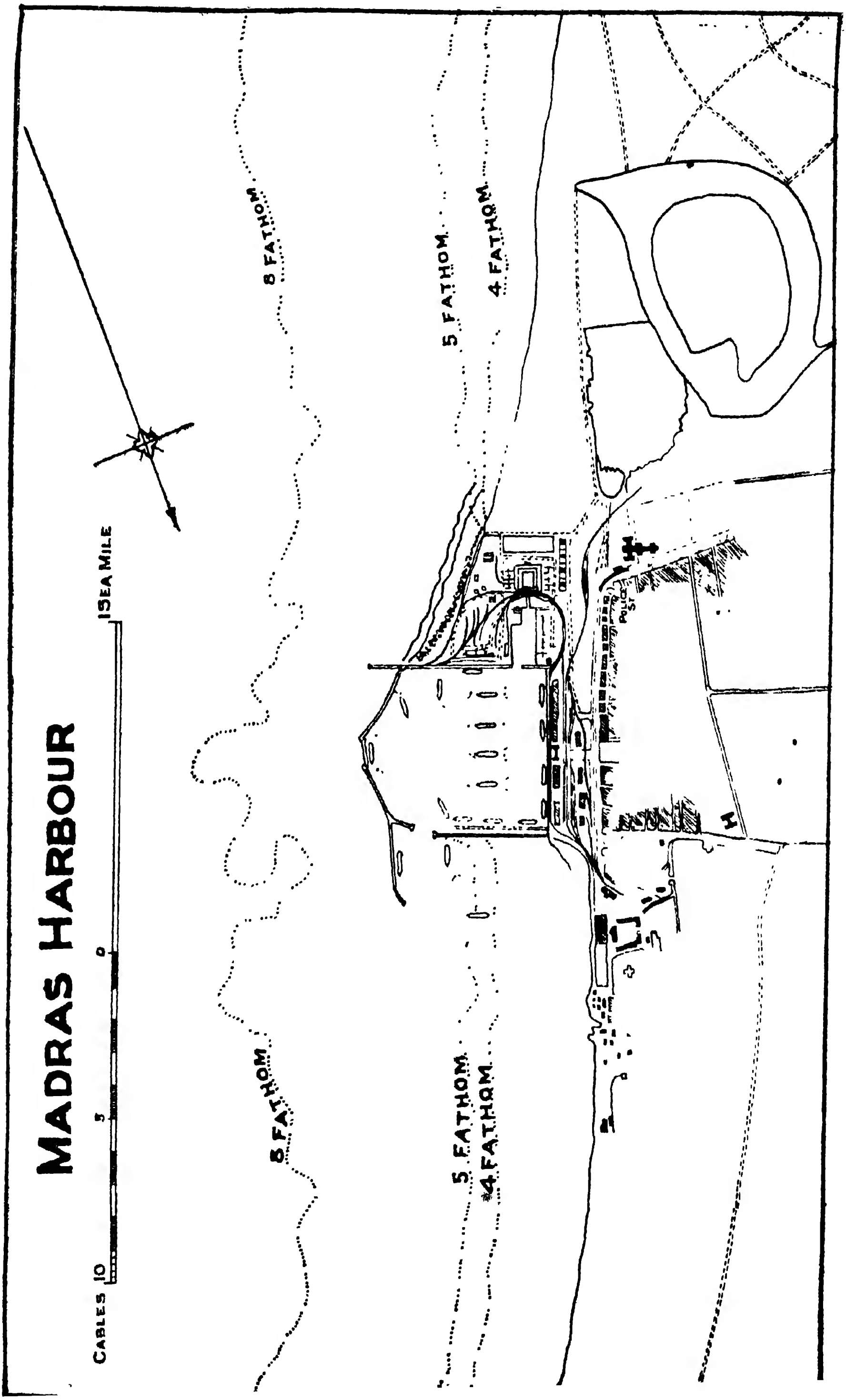
R. M. S. "MOOLTAN" 20,700 Tons, BERTHING AT BALLARD PIER.

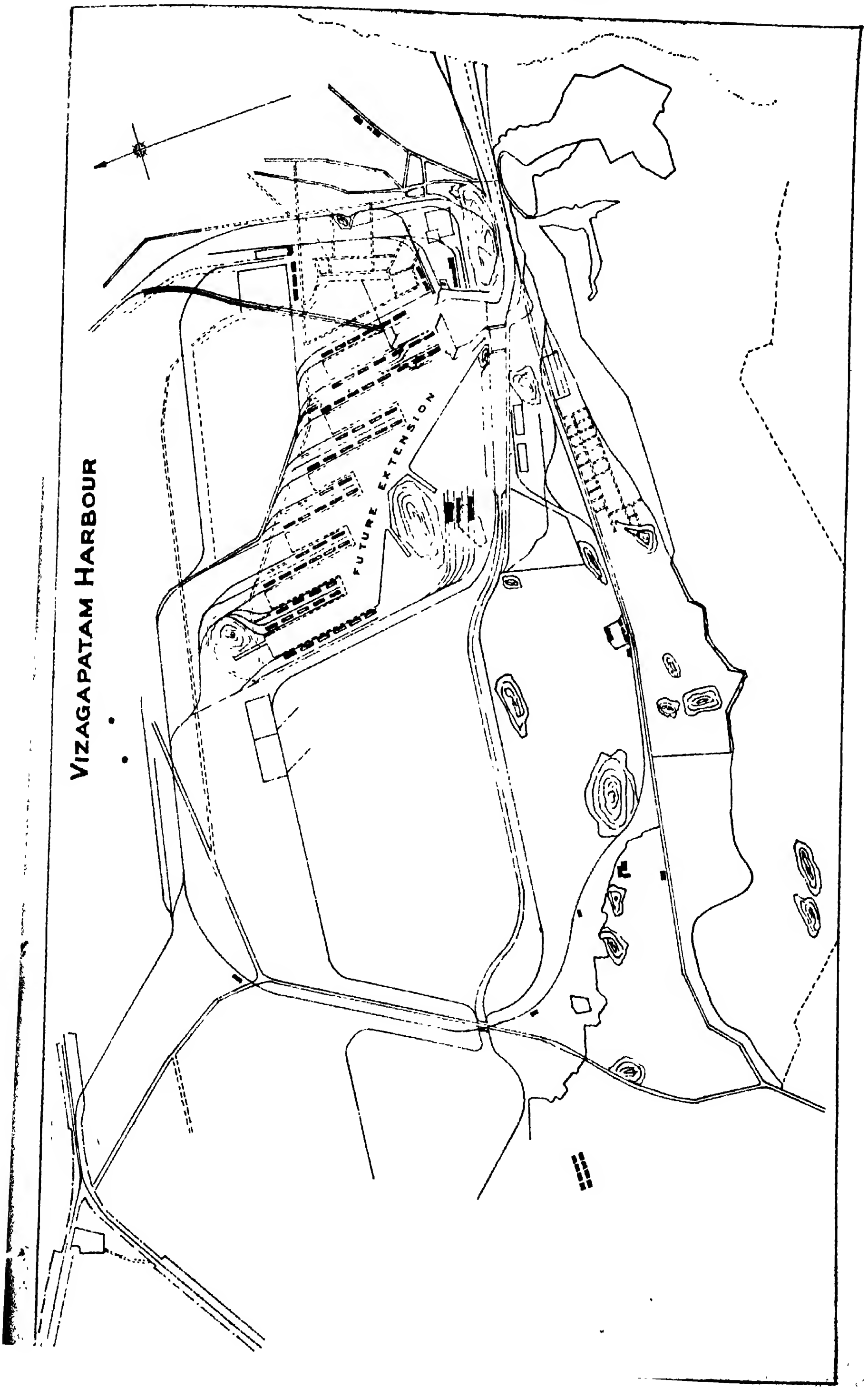

CALCUTTA PORT
P.C. BOUNDARY
KING GEORGES
DOCKS
DOCK No 2
DOCK No 1
RIVER
HOOGHLY
TIMBER PONDS
KIDDERPUR
HOWRAH
FORT WILLIAM
HASTINGS
MOMINPUR
DURGAPUR
RADHANAGAR
SHAHPUR
MOYRPUR

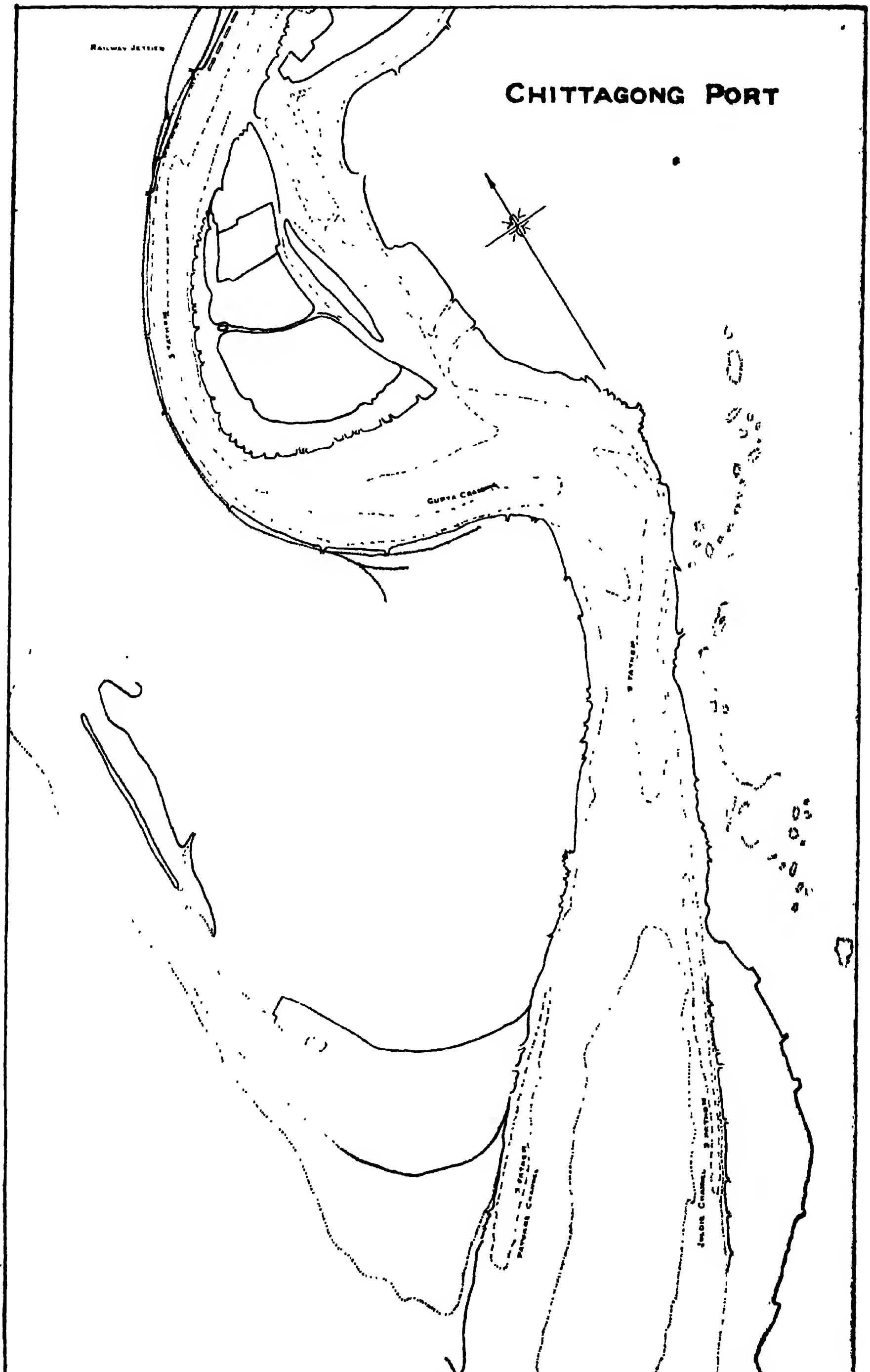

PORT OF BOMBAY

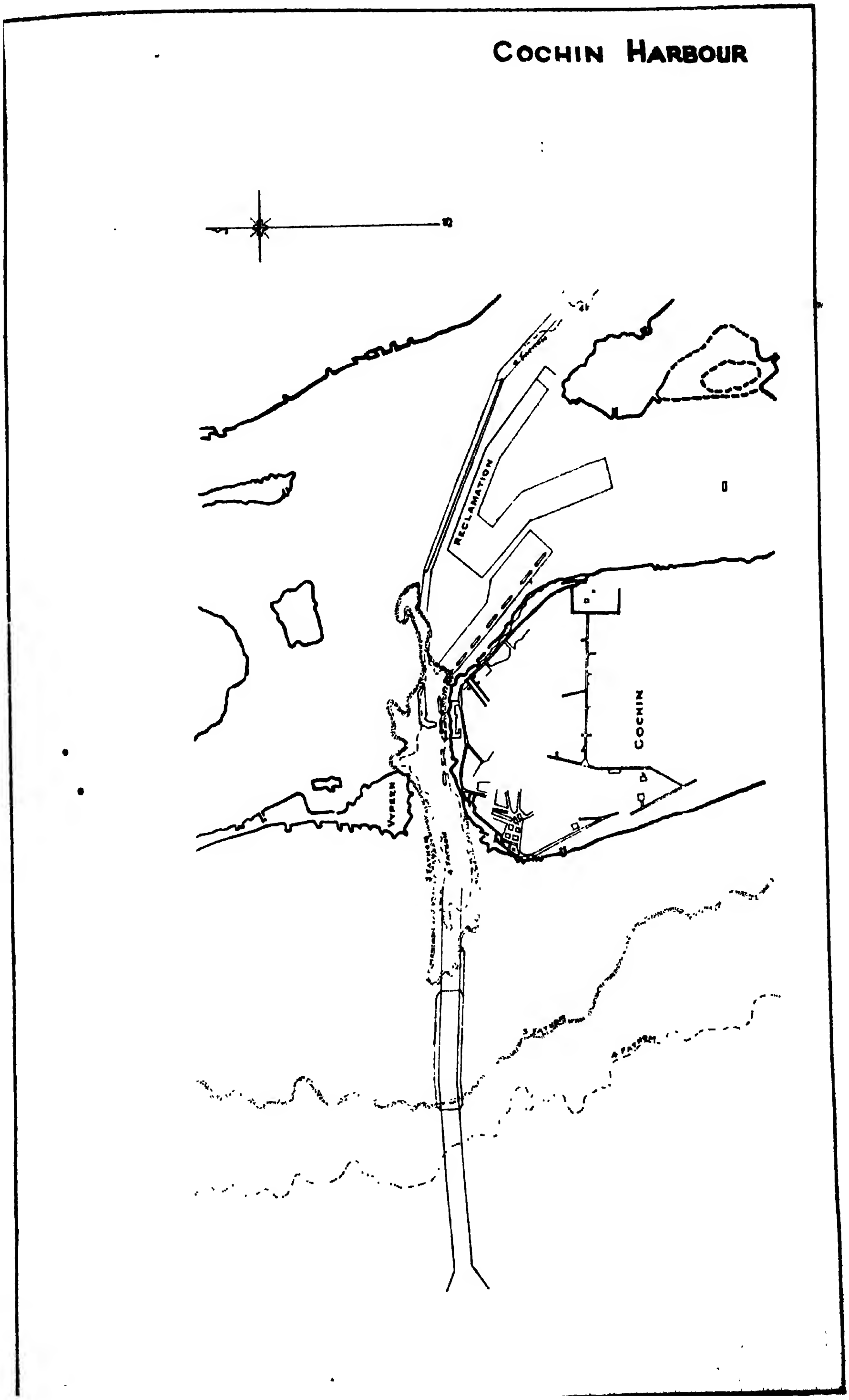

KARACHI HARBOUR


RANGOON HARBOUR


MADRAS HARBOUR
CABLES 10
5
0
1 SEA MILE
8 FATHOM
8 FATHOM
5 FATHOM
4 FATHOM
5 FATHOM
4 FATHOM
POLICE ST


VIZAGAPATAM HARBOUR
FUTURE EXTENSION


CHITTAGONG PORT
Railway Jetties


COCHIN HARBOUR
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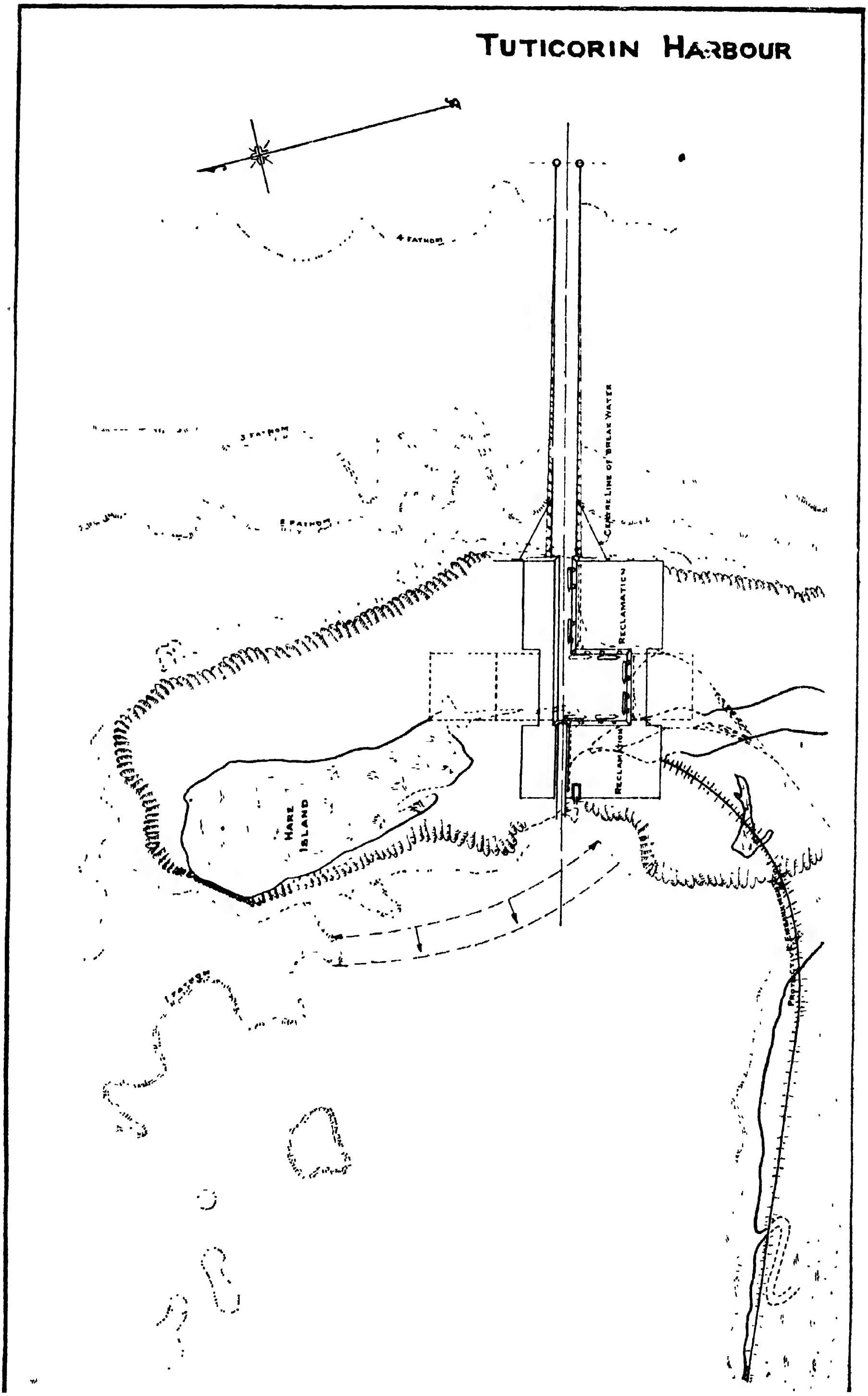
TUTICORIN HARBOUR
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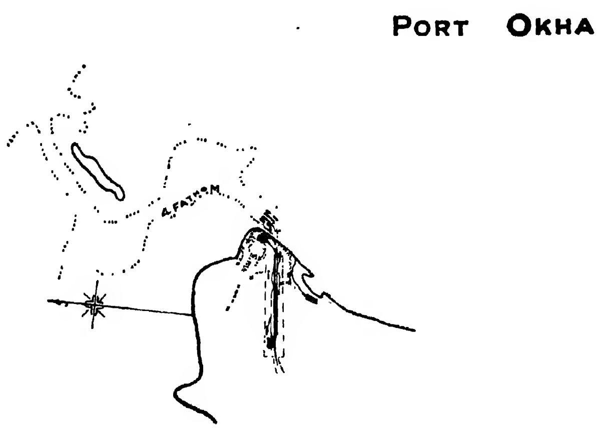
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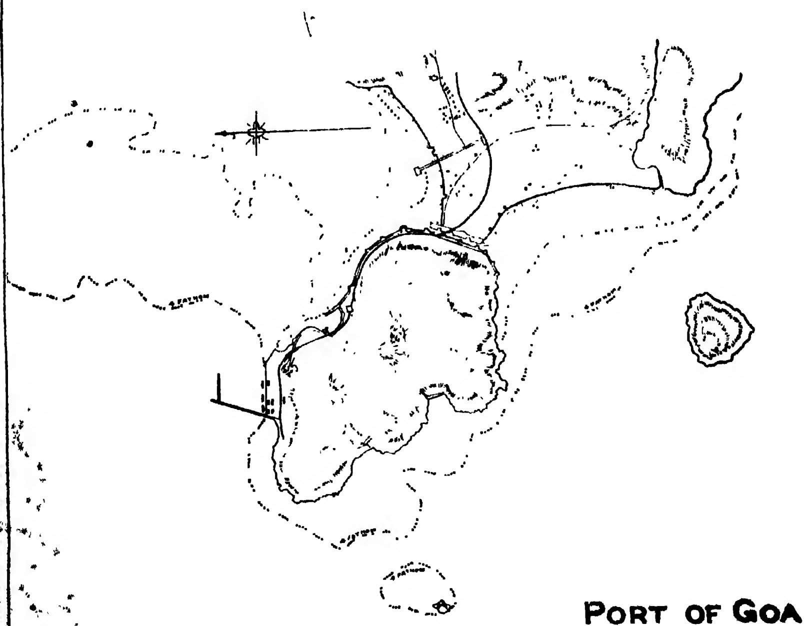

PORT OF GOA

THE
SEVENTH ANNUAL DINNER.

The Seventh Annual Dinner of the Institution of Engineers (India) was held in the Taj Mahal Hotel, Bombay, on Wednesday, December 1, 1926.

Mr. W. H. Neilson, Chairman of the Bombay Port Trust and President of the Institution, presided. His Excellency Sir Leslie Wilson, the Governor of Bombay, was the principal guest. The other guests included the Hon. Sir Chunilal V. Mehta, the Hon. Mr. J. L. Rieu, the Hon. Mr. J. E. B. Hotson, Mr. P. G. Rogers, Mr. H. K. Kirpalani, Mr. J. A. Kay, Mr. R. M. Chinoy, Mr. A. H. Byrt, and Mr. H. B. Edwards.

His Excellency Sir Leslie Wilson proposed the toast "The King-Emperor."

The President in proposing the toast "Our Guests," said:

Your Excellency and Gentlemen:—May I first start with a note of apology. It is well known that Engineers are not versed in the art of speaking, the gift of the silver tongue is not theirs, they try to make out that they are—above all things—practical and not verbose. Post-prandial oratory does not enter into their scheme of things—they can execute but they cannot dance. It is on an occasion like this that one feels that one has not the consolation, perhaps the only consolation of Daniel on entering the lions' den when he realised that there would be no after-dinner speeches.

Let this therefore be my apologia and pardon my obvious shortcomings and any unhappy hesitations that may occur.

We are delighted and honoured to have with us to-night as our Principal Guest His Excellency, Sir Leslie Wilson, Governor of Bombay. Although we are celebrating our Seventh Annual Dinner, this is the first time we have had the pleasure of having a Governor of Bombay present. The reason of this is because we hold our meetings at different centres each year, and this year Bombay has been chosen as a venue. We held one prior meeting here in 1922, when unfortunately the then Governor, Sir George (now Lord) Lloyd was unable to be present. In 1923, however,

he was Principal Guest at the Annual Dinner held by the Bombay Local Association of the Institution in this hotel.

His Excellency, by his presence here to-night, has shown his sympathy with our aims and objects, and he has already identified himself closely with the many Engineering schemes in his Province. We place a great value on his sympathy and we can assure him that we value him for his kindliness, we value him for his openness, we value him for his frankness and above all, we value him as a man, who played such a gallant and forward part in that terrible epic at Gallipoli.

To our other Guests, we extend a hearty and cordial welcome. To those of us who live in Bombay, their names are household words. They represent Government and Trade—the one inter-dependent on the other. The peace and prosperity of the Bombay Presidency lies in their hands, and I think that you will agree that these two vital matters could not be in a worthier keeping.

We, Engineers, can certainly help to keep the peace, and we can, I think just as certainly help in the prosperity of the country. Our work is creative and, in some cases, preventive. In either case it is beneficent and in all cases, it ought to be economic. The Engineer can do a great deal in stamping out disease, such as malaria, and the very fact of bringing a pure water supply to a town or large area should go far to lower the death-rate. He can also, if he has sufficient funds, make the desert blossom like a rose. As Your Excellency has just come from a place where this effort is being made, perhaps you will be kind enough to tell us how the work is progressing. Of one thing I am certain, namely, that it will be a success, and that it will bring prosperity to the country generally. Your Excellency is also shortly going to "open" the Bhandardara Dam, one of the highest dams in the world. Both these great schemes are economic, and we all hope that with these and other major works, together with the steady industrialisation of India and an immediate, though perhaps problematic, revival in trade, we may enter a new era of contentment and happiness.

And now, Gentlemen, I think I have spoken long enoguh. The pale wraith of St. Andrew, we trust, is at rest again and we have to put our shoulders to the wheel once more. The labours of His Excellency are well known to us, and with his time so thoroughly and generously occupied, we feel it all the more honour that he should grace our festival to-night.

I, therefore, ask you to drink to the health, long life and happiness of His Excellency Sir Leslie Wilson and Our Guests.

I have very great pleasure in announcing that His Excellency has consented to become an Honorary Member of the Institution.

His Excellency Sir Leslie Wilson, in responding to the toast "Our Guests," said :—

"Mr. Chairman and Gentlemen :—On behalf of myself and the other Guests to whom you have extended your hospitality to-night I desire to express our sincere thanks to your generous welcome to this toast. It is a source of great pleasure to me and to those for whom I am speaking to have the opportunity, as we have to-night, of meeting so many representatives of the great profession to which you all belong—representatives, coming, as you do, from every part of India. I am glad, indeed, that this is the first occasion on which the Governor has been present at your gathering.

"I notice—it is a rather curious fact—that all these gatherings of professional gentlemen seem to take place at the most opportune moments. I presume it is only a coincidence, but undoubtedly it is a fact, that you are visiting Bombay at the same time as the M.C.C. team is doing. I can only trust that your deliberations will not be interrupted in any way, by the happenings on the Gymkhana ground.

"Gentlemen, when I started to-night I felt that I really ought not to speak again. I am reminded of a very old story, but it is very appropriate. It is a Scotch story, the story of a Scotch lad and a Scotch lassie, who went out for a walk together. The Scoch lad was of rather taciturn disposition, and having walked for about an hour he had said nothing. At the end of the hour he turned round to the lassie and said: 'Maggie, will you marry me?' Maggie said: 'I will.' They walked on for another hour, but nothing was said; so, Maggie said: 'I say, Jack, you are very silent to-night?' He replied: 'I think I have already said too much.'

"Gentlemen, this is the fourth speech I have made within the last 24 hours. I spoke last night at the St. Andrew's dinner. Earlier in the day I addressed a large audience of representative medical men and ladies. And then I proceeded—after watching the cricket for half an hour—to talk on commerce at the College of Commerce, and I was starting a disquisition on the value of the rupee and gold, when I saw Sir Victor Sassoon in front of me, so my speech was considerably interrupted. I have now come here to have the opportunity of meeting you, Gentlemen, and I feel really that the story I have told you is very apt.

"I did not agree with the Chairman when he said that engineers were voracious but not verbose. I do not know what he meant by 'voracious,' unless he alluded to the meal. I will testify to their voracity, but not to their verbosity. But, I thoroughly endorse the statement that engineers are not versed in the art of speaking. I put aside my personal experience with regard to the

engineers of the Bombay Presidency, and I will ask you to await the arrival in India of the report, the full report of the Back Bay Committee. If you can then honestly say that engineers cannot express their opinions with all the verbosity at the command of the politicians, I may then be prepared to agree with the statement of your Chairman.

"You, Mr. Chairman, have said that engineers are responsible to a very large extent for the prosperity and the peace of any country. It is true that the prosperity, particularly of India, depends on the efforts of engineers, and 'prosperity' is after all only another word for 'peace'. You, the engineers of India, who have worked in India, have been responsible, and your predecessors have been responsible, for great schemes which have been undertaken for the purpose of assisting the agriculturists of India. By your work, your labours and your ability, you have served India and have contributed to a great extent to that peace and prosperity of India which we are happy to enjoy to-day.

"I personally am not in a position to speak for any other Presidency or Province than that of Bombay. In Bombay, owing to the efforts of the engineers, we have something like 10 per cent. of the cultivable area under irrigation. With the Sukkur Barrage scheme, we shall have something like 17 per cent. I hope very sincerely that the efforts which the Bombay Governments made in the past and the Bombay Government are making at present will not be the last effort we shall make in this direction.

"You have said, Mr. Chairman, that the works of the engineers are economic. That is one of the problems at the moment, which we, as a Government, have to compute. I am speaking in the presence of my Finance Member, who, I know, will cordially agree with every word I say. Our difficulties with many of the works is not due to any fault of the engineering officers, but that the works are not economical. Of course, it is very difficult to gauge the economic value of an engineering work, because you have to put on one side the value which you will receive from the irrigation of barren districts, which, of course, has a great economic value of its own.

"You, Mr. Chairman, have spoken of some of the great works which we are carrying out in Bombay, many of which are approaching completion, some of which are only approaching their most difficult stage. It is true that in a few days' time I am going to open the Bhandardara Dam. I do not know how to open a dam. But, I am called upon to open everything that has to be opened.

Well, I have visited the Bhandardara Dam, and I really think it is another tribute to the great ability of the engineers who have

served this Presidency in the past and are serving it even now. It is, as you Mr. Chairman have said, the highest dam in the World—275 feet high. When fully completed it, together with the Canals which will flow from it, will be of the greatest importance to the area to which water will be supplied.

"We have another dam, which is very nearly completed, Bhatgar Dam. It is the longest dam. which is another feat of the engineers, and of which the engineers of the Bombay Presidency have every reason to be proud indeed. When that dam is completed, when it does all the work which it is expected to do and when it begins to help the cultivation of the large area for which it is planned, it will be of the greatest benefit to the whole Presidency of Bombay.

"Now, you have alluded to the greatest effort which the engineers of the Bombay Presidency have ever undertaken, and that is the great Sukkur Barrage scheme. Since I arrived in Bombay I have been inundated with correspondence from a number of people who did not believe in its success. I have been lately attacked very severely by these people who are telling me that the Sukkur Barrage scheme is going to be another Back Bay Reclamation. I need hardly state that a scheme of the magnitude of the Sukkur Barrage involving, as it does, an enormous capital cost of something approaching 23 or 24 crores of rupees, is a scheme which is receiving the most careful consideration from everybody concerned. Now, I think we are extremely fortunate in the Bombay Presidency in having engineers of the type we have, who are carrying out this great undertaking in Sind under the most difficult climatic and other conditions. I can say from my own experience and I can say from the information I have received from all those officers whose advice I value that I have no doubt in my mind that the Sukkur Barrage is going to be the greatest success as compared with any of the great engineering schemes of the world. I am not saying that without due consideration. We have examined, we have re-examined we have re-re-examined all the estimates of that scheme and we are convinced that up to the moment there is not the slightest possible doubt that the scheme will be carried through to every success.

"You have alluded, Mr. Chairman, to the efforts which are named after different people. I have only one thing named after me in this Presidency, and I think it is the only thing I have liked to be named afer me. It is the first excavator, which was worked on the Sukkur Barrage scheme—'the Wilson Excavator'—I started it myself. That was nearly three years ago. That was the

first time we dug. We started to dig one of the first of the three big canals. We have three big canals, each of them not so deep —but larger and wider than the Suez Canal, traversing hundreds of miles of sand to provide water for this large area which we propose to irrigate under the Sukkur Barrage scheme.

"Since that day I have visited Sindh each year and have had the opportunity of seeing for myself the progress which has been made in this extraordinary scheme. The progress has exceeded the anticipation of the most optimistic calculations of those eminent engineers who are conducting the works. It is only a matter of a few days ago that I saw the central canal having progressed more miles than could possibly have been anticipated even by those who had hoped for the very best results. But, gentlemen, we must realise that in a scheme of this magnitude, presenting, as it does, engineering difficulties perhaps hitherto unknown in the engineering world, there will be difficulties in the future. At the moment we are starting—I say 'we', I mean the engineers up there—putting into both banks coffer-dams which are to enable the engineers to build the regulators for these three great canals. They have got to finish the regulators before the Indus comes down again. When these completed coffer-dams have been pushed out from each bank in spite of great engineering difficulties, one hopes that everything will go on without any further difficulties occurring. But the Indus, as many of you know, has a name in the North as the Mad Indus. One never knows perhaps from one year to the other what the Indus is going to do. One cannot hope that the whole of the scheme is going to be carried through without some difficulty, without perhaps something going wrong in one year, without perhaps one portion of the great dam, which has to be completed every year before the Indus comes down, meeting with some accident owing to the Indus coming down too soon before the work is finished, and as a result the whole area being filled with water and being lost. I know that if that thing happens all the critics of the scheme will say: 'Well, I told you so.' But we must know that everything cannot possibly go on according to previous plans and we must face the possibility one year or another of our having to meet with unforeseen difficulties. These difficulties are bound to occur in a scheme of the magnitude and importance of the Sukkur Barrage, a scheme which is unprecedented in its magnitude, the biggest scheme that has ever been undertaken by the engineering fraternity in the whole world.

"Your Chairman is responsible for getting me on this subject. I really did not intend to talk to you on this subject. I am afraid I am talking on subjects which affect the Bombay Presidency only.

Although I take great interest in engineering projects outside the Bombay Presidency yet I cannot talk on such subjects as for example The Punjab and Kangra irrigation schemes with intimate knowledge. I do want, however, to say one word about the engineering profession. It is appropriate perhaps that I should say this to you, representing, as you do, engineers from all parts of India. It seems to me, coming out as a stranger to India, as I did three years ago, the great work, the most valuable work of the engineers who have served in the past has never really received adequate recognition. I cannot talk of other parts of India, but when I go round to these great engineering works now providing irrigation for ten per cent. of the cultivable area of this Presidency, when I think of the names of men like Fife and Beale—men who have been responsible and practically entirely responsible for all the designs of these great schemes of the past, schemes which we are now carrying out and schemes which we still propose to carry out in the future—I cannot help thinking that their names have not been sufficiently appreciated and that the value of their services has not been sufficiently realised by those people whom they have benefited so much.

"It was said of the great Christopher Wren, who built St. Pauls, as you all know, when somebody asked: Why have they not put up a monument to him in London?' the answer was 'If you want to find out a monument to him look around!' You may give the same answer about those engineers who served this Presidency so well, so ably and so loyally. I would rather see their names were remembered by their names being connected with some of these great undertakings for which they were entirely responsible, and I trust that we shall be able at some moment or other to see that this is carried into effect in the future.

"I deeply appreciate, Mr. Chairman, the honour which you have been good enough to confer upon me by asking me to become an Honorary Member of the Institution of Engineers. I trust that it does not entail any work or responsibility, nor that it will require any more speech-making on my part. I can only say on behalf of myself and my fellow-guests that we are intensely grateful to you, Mr. Chairman, and to the other members of this Institution for your invitation to us this evening. It has been a great privilege to have the opportunity of meeting engineers from every part of India, and I, as the head of the administration in Bombay, offer you the most sincere and hearty welcome to our Presidency."

Sir Chunilal V. Mehta in proposing the toast "The Institution of Engineers (India)," said:—"Your Excellency, Mr. Chairman and gentlemen,—Much as I appreciate the honour of being asked to propose the toast of the Institution, I cannot help thinking that the

duty should have fallen to the lot of my Hon. friend and colleague who is away now inspecting the greatest irrigation scheme that the Bombay Government have ever had to deal with. I am referring to the Hon. Mr. Cowasji Jehangir, the Member for Irrigation.

"My own work in connection with engineering has been cast in very much humbler mould. As Revenue Member I was interested in the construction of wells and tanks, which I notice your Vice-President referred to only yesterday as works of a bygone age. I have no doubt, however, that if these works were carried out, as, indeed, they were intended to be carried out, we should cover a very much larger area, and we should benefit also a larger number of men than can be benefited by the highest dam in the world or the dam which has the largest amount of masonry in the world. Therefore, I took advantage of my superintending engineer and appointed him to advise us as to the scope of this work.

"Gentlemen, when I thought of what I should say here to-night in proposing this toast, I cast about for a definition of the word 'engineer'. I have come across a good many definitions. But, I wanted the correct one, and the most appropriate one I found was that 'the engineer is he who does for one rupee what every fool can do for two'. It seems to me it is a very correct definition. Since the days of Solomon engineers were required, I believe, not only for speculative building but for actual construction as well. And from that time Governments in all countries, I believe, have been in the hands of engineers. Certainly, our Government has been. And, I rather doubt whether even the doughty Scotsmen unenforced by the strong waters that flow at St. Andrew's Night dinner, would care to tackle the engineer or to keep him under check.

"On a further pursuit and further examination, I found, on asking the advice of an engineer friend to let me know some more particulars about this Institution, about its aims and objects and what it has set out to do, I got in reply the memorandum of the Institution with certain words underlined, which my friend perhaps thought would particularly appeal to me as a custodian of public finance. One of your principal objects is that you will foster not only the science and practice, but also the business of engineering. I am particularly interested to notice the word 'business in engineering'; because I cannot help thinking that while a few experts perhaps have confined their interests only to the technical side of their work, to the laymen and the taxpayers what is of the utmost interest is the business side; for it provides the sinews of war for their various activities. Moreover, your

President just now stressed the particular point about the economic development of engineering.

"I will give you an illustration of how great an importance ought to be attached to this part of engineering. It is the fact that in this Presidency alone in the current year, while in the budget provision is made for a total expenditure of 22 crores of rupees, no less than 9 crores or just about 40 per cent. are to be spent on either engineering works or through the agency of engineers. You can well imagine how failure to come up to the high standard which is conveyed in the definition may affect the solvency or even the safety of the State.

"I found further that your activities are not limited merely to this Presidency or to this country and that your business is to be extended beyond India. Wherever we look we find an abundance of both material and men which Nature has favoured this country with, and it is to the engineers that we always turn for manufacturing our raw material and for transporting it to the markets. It is therefore of the utmost importance that engineers should not only be supported but that the engineering profession as such should be fostered, and I look forward to the day——and I hope that subsequent Finance Members will have a full purse with which to endow several engineering colleges in this Presidency—when the ablest sons of the land will devote their energies and their future life to the honourable—and, I hope, the lucrative—profession of engineering.

"Gentlemen, the presence of Col. Willis on my left reminds me of a little experience which I had and which again shows how difficult it is to get the better of an engineer. You may, perhaps, be aware that in Nasik there used to be an acetone factory. That factory cost the Central Government something like 50 lakhs of rupees. After much bargaining, the Bombay Government happened to buy it for some 17½ lakhs of rupees. It was the one—I believe the only—transaction in which the Bombay Government on the Finance side has got the better of a superior Government. That factory we converted into a distillery, in furtherance of the policy of Government. That factory has steadily continued to pay about 75 per cent.

"But, some three years after that down comes upon us a representative of the Central Government, Col. Willis, and wants to make some very profitable arrangements on his side. The Hon. Minister brought up the papers to me for some advice as an ex-Minister, and I at once saw that Col. Willis was trying to get something back for the Central Government. I proposed certain other terms, and—I must compliment this gentleman upon both his powers of negotiation and diplomacy—he did not accept these

terms at once, but wanted an interview and at that interview finally agreed to them. But that was not all. It is quite possible that in a transaction both sides may feel equally happy. I felt certainly somewhat happy, but, to my dismay, I discovered some few days afterwards that Col. Willis informed a certain gentleman that he thought he had got an excellent bargain out of me. I only hope that Col. Willis will, perhaps, explain that the advantages which we got from the Central Government are not going to be jeopardised. I wish to give you the toast of this distinguished Institution of Engineers and its prosperity."

Lt.-Col. G. H. Willis in reply said:

At the behest of the Council, a behest which I feel does me great honour, I rise to reply to the toast of the Institution of Engineers (India) so ably proposed by Sir Chunilal Mehta. I have had—as some of you know—a long and very intimate connexion with the Institution, especially in its earlier years. I and the then Secretary drafted the whole of the Articles of Association and By-laws and we ought to be very much flattered at the comparatively few alterations which have since been found necessary. This preface is merely to exhibit my qualification to speak for the Institution, of which I have had the honour to be a Member of Council since its incorporation, and the still greater honour of filling the Presidential chair in 1921-22, which was the last occasion on which we held our annual dinner in Bombay.

As an old hand, I congratulate Mr. Neilson on the wise choice which the Institution has made in selecting him as President for this coming year. He will find it a very busy year and, as we know, he is a busy man already; but we all feel sure that when he relinquishes office—and judging by my own experience he will do it with some relief--he will leave the Institution stronger in both numbers and influence and in every way the better for having had as its head an engineer who combines with high technical qualifications an excellent knowledge of affairs.

For one moment I wish to draw your attention to the debt we owe to the excellent work and the loyal service of our permanent staff. Our Secretary has proved himself—not irreplaceable, we are none of us that—but of such great value owing to his intimate acquaintance with our affairs, his devotion to duty, and his whole-hearted zeal for the welfare of the Society he serves that to lose him would be a disaster and I am sure I have you with me in according him our very real thanks.

Now I want to take you with me a little way into the relation that should exist, and happily does to some extent exist between

India and its Institution of Engineers. Your Excellency, to you and our other guests here to-night and, through you, to the people of India I want, if I can, to make it plain that the Institution exists primarily to benefit India as a whole by providing for the profession a Society which is qualified to prescribe standards of technical acquirements, to nurture engineering knowledge and research by all suitable means, to advise Government and others when consulted on Engineering problems, and to uphold the dignity of the profession so that from coming generations many of the best intellects may be attracted to a calling which promises absorbing work, adequate consideration and reasonable remuneration.

The Institution claims that it has already gone far in its effort to attain these aims. Started only seven years ago with a small membership we are now 1,000 strong. We number among our members most of the outstanding engineers in all branches throughout the country. We have published many very excellent professional papers of which some will undoubtedly become classics. Some Governments and institutions prescribe corporate membership of the Institution as a qualifications for appointments. It is to be hoped that this will continue and spread till the Institution fully occupies in India the position which in England is held by the great engineering institutions there.

We have been consulted by the Imperial Government, who entrust the country's representation on the British Engineering Standards and other important organizations to the Institution, and by Provincial Governments, on various vital matters including the education and qualification of engineers, the mitigation of floods in Bengal, and the perennial Hooghly Bridge and I venture to say that the Institution's recommendations have not been the least useful of those received. How could they be? since the Institution's corporate knowledge of engineering in all its phases throughout the country places it in the unique position of being able with certainty to indicate the man or men who are most suitable to advise. And let me say here that I am sure that whenever the Council of the Institution is consulted as to the right men to advise, they will by no means confine their selection to the Institution if in their opinion the most suitable persons are unfortunately not among our members. For it is with great regret that we still find certain eminent and eminently suitable engineers outside our organization. A little wider outlook and a little more public spirit should bring them in. We are not bound by the laws of freemasonry so that we can and do say to all qualified engineers "Join us and help the engineering profession in India to that position and influence which it should have if it is to minister adequately to the present-day needs of the country."

In the name of the Institution I thank you most heartily for your cordial acceptance of the toast so ably voiced by Sir Chunilal Mehta. It is only once in about every five years that we are able to meet in Bombay as an Institution though you have with you always the Bombay Association of the Institution. Let me beg of you to use that Association, and through it the Institution, on all suitable occasions. By so doing, while you will benefit yourselves, you will benefit us, for every call on our Institution to prove its use acts as a spur in the direction which we, who have its welfare so much at heart, ardently desire that it should take, and that direction is onward and upward.

THE RAILLESS OR TRACKLESS TROLLEY SYSTEM"

BY

A. LENNOX STANTON (Member).

INTRODUCTION.

In view of proposals recently put forward for introducing the "railless" or trackless trolley system into the suburbs of Bombay, it is an opportune time to draw attention to the advantages, facilities and limitations, presented by this system of passenger transportation. During the autumn of 1925, advantage was taken by the author, of opportunities presented for making a personal inspection of such facilities in Great Britain, together with an investigation of the cost aspect, with a view to the data gathered together being of service at a later date to the Government of Bombay; since however the trackless trolley system presents aspects of increasing interest to the general community, it was deemed advantageous to place some of the information before this Institution in the form of a paper, in the hope that it may serve to focus attention upon an additional aid to certain existing transport services in India. Furthermore, as it cannot be doubted, numerous conditions are known to exist in other parts of India, calling for improved passenger traffic facilities, where the capital expenditure of a tramway may or may not be prohibitive, the data now presented, regardless of either condition, should nevertheless prove useful, to whomsoever may be called upon to consider such schemes.

DEVELOPMENTS TO DATE.

Two decades ago in Great Britain, tramway undertakings formed the most efficient method in vogue for rapidly dealing with the community passenger traffic of large cities and towns. During the decade immediately preceding the war, it is probable no aspect in the field of general public utilities, made a greater showing of

rapid progress than that related to electrically operated tramway systems. In particular was this true, as a phase of development on the part of Municipal Corporations and in numerous cases so anxious were the local authorities to secure the complete control of tramways, they did not wait for the expiration of private enterprise leases, but everywhere endeavoured to buy out the operating companies on profitable terms to the community. The extent to which this growth attained may be judged, from the following statistics for the year 1923-24 of 170 Tramway Undertakings owned and controlled by local authorities alone in Great Britain :—

Capital expenditure.	£71,341,947
Gross receipts.	£23,823,170
Working expenses.	£18,554,128
Net Receipts	£ 5,269,042
Car miles run	298,542,973
Passengers carried	3,783,562,310

After the payment of working expenses, revenue available was chiefly diverted to :—

(a) The repayment of money borrowed to carry out the initial enterprise.

(b) Making necessary provision against depreciation and reserve.

(c) The relief of rates.

Available statistics covering 91 undertakings for the same year, show that :—

66 earned a surplus.

25 showed a deficit.

21 only contributed to the rates.

70 failed to contribute to the rates.

59 contributed to reserve.

32 failed to contribute to reserve.

31 failed to contribute to either the rates or reserve.

Although certain undertakings are still in a flourishing condition, the position taken as a whole is obviously far from being a satisfactory one and therefore the question of maintaining, or extending existing facilities, has become a matter of increasing importance to the rate-payer. The reasons are not far to seek, for during the war, the maintenance of both car tracks and rolling

stock suffered from serious neglect. In particular, unless heavy losses were faced, the post-war renewal costs of car tracks rose to an extent that prohibited re-construction, on sections from which but a low revenue return was obtainable. In addition, as the result of either actual or threatened competition, from a highly organised development of the petrol motor omnibus, tramway revenues as a whole have been seriously reduced and in certain types of traffic areas, the consideration of alternatives to the regular tied to track traffic facilities, has of necessity, had to be given consideration. At present these alternatives are confined to:—

(1) The Petrol vehicle.

(2) The Petrol electric vehicle.

(3) The Railless or trackless trolley vehicle.

Of these, (having special regard to the 170 undertakings), the last mentioned, quite apart from all other considerations, assumes an importance in Great Britain of special significance, owing to its adoption providing an avenue for either maintaining or increasing the revenue obtainable from electric supply services, owned in the majority of cases, by the same local authority as that to which the tramway undertaking belongs. It follows in such cases the adoption of the railless system is bound to prove of great advantage since the combination of public utilities is, or should be, productive of economic objectives in other directions. A threatened competition may therefore be averted and prevailing losses, competitive or otherwise, due to traffic conditions, may be converted into profits. Moreover in areas where the cost of laying down and maintaining tramway tracks has become prohibitive, the trolley-bus, as it s sometimes called, is even displacing the older system, either in sections, or in entirety. Cases of interest which ably present the strength of the position which railless traction is gradually attaining are as follows:—

(1) *Ashton—Oldham.* During 1925 the Ashton Under-Lyne Corporation took over a tramway system from a private Company, the permanent way of which was worn out. The railless system was adopted as the cheaper alternative to renewals, single deck trolley buses of the low loading type and having a seating capacity for 37 passengers being utilised.

(2) *Birmingham Corporation.* In the year 1921 the Corporation was faced with the re-construction of a very large amount of permanent way and one route—the Nechells—carrying a very light traffic, had got into such

a bad condition, that it was no longer possible to postpone dealing with the problem it presented. After exhaustive enquiries and much consideration, it was decided to abandon the tramway and adopt the trackless trolley in its place.

The following estimated figures were put forward:—

To re-construct the Nechells tramway for a continuance of tramway traffic would cost:—		£90,000
To instal Trolley omnibuses would cost:—		
12 Trolley vehicles ..	£36,000	
Alteration to over-head lines ...	£ 3,000	
Taking up tramways and making good the route for ordinary traffic. ...	£15,000	
	£54,000	
Less:—		
Value of 12 tramcars transferred to other routes. ..	£18,000	£36,000

Estimates of Receipts, etc.:—

Tramways:—		
Receipt based on previous years		£28,300
Expenses 80%		£22,640
Gross Profit		£ 5,660
If the amount required for reconstruction was made the subject of a Loan, the Interest and Sinking Fund charges would amount to		£ 9,000
Loss ...		£ 3,340
Trolley buses:		
Receipts ...		£28,300
Expenses 80% ...	£22,640	
Less:—Saving 1¼d. per mile P. W. repairs ...	£ 1,562	£21,078
Gross Profit ...		£ 7,222
Interest and Sinking Fund charges ...		£ 4,100
Profit ...		£ 3,122

The foregoing figures showed that there would be an estimated saving in capital expenditure of £54,000 and an estimated profit on working of Trolley omnibuses of £3,122 per annum, after paying Interest and Sinking Fund on the new capital required, as against a loss of £3,340 in the case of a tram service. The new system was opened for traffic during November, 1922, and the extent to which the section of route in question, now acts as a feeder to the regular tied to track system, may be judged from the following statement extract of receipts covering period April 1st, 1924, to March 31st, 1925 :—

Miles run	...	369,186
Passengers carried	...	5,547,200
Receipts	...	£27,845-5-3½

The cars in use are of a double-deck type with the addition of a top cover, they have proved very popular with the public, run with great smoothness, are practically noiseless and can seat 51 passengers.

(3) *Bradford Corporation.*—A pioneer of the railless system, which has been in operation on suburban routes since 1911. In this city the financial aspect brought about by the combined costs of maintenance and tramway reconstruction, have called for an investigation of the position as presented by proposals to substitute the railless system in entirety for the older system, based on a cost of conversion spread over a period of fifteen years. That such proposals call for the exercise of sound judgment and wide experience, will be self-evident from the following figures for year ended March 1924, and subsequent extract report data :—

Tramway service commenced in the year 1898.

Route miles in service	...	60.28
Total capital expended	..	£1,422,258
Traffic Revenue	...	£ 624,778
Operating Costs	...	£ 504,931
Car miles run	...	6,863,348
Passengers carried	..	92,683,421

The railless section of the system represents a capital expenditure of £28,584, operating on 9 m. 39 ch. of route and during the year quoted 408,236 car miles were run carrying 3,601,004 passengers.

In a report circulated to members of the City Council Mr. R. H. Wilkinson, the General Manager of the Tramways, states

that the approximate saving that would be effected each year in capital charges as against reconstructing the tramways would be £6,600 and gives the following figures as indicating the approximate results likely to be obtained from three possible means of transport:—

	Tramways	Railless	Buses
Total cost	£107,623	£50,849	£43,649
Working expenses	9,126	10,333	12,271
Interest and Sinking Fund	8,918	5,049	6,894
Total costs of operation	18,044	15,382	19,165
Income	9,633	11,191	11,191
Estimated annual loss	8,411	*4,191	7,974

*Estimated for first 15 years.

Special attention is also drawn in the report to the point, that the Corporation Electricity Department is losing a good customer in the event of a decision to adopt motor buses. In this case, the Tramway Department purchase their power from the Electricity Department for 1¼d. per unit and during the year for which data is given (1924), the number of units used was 15,496,787. This aspect cannot therefore be ignored.

(4) *Bournemouth*.—Here also, the heavy cost of re-construction, estimated at approx. £30,000 has rendered it imperative to consider alternative proposals.

(5) *Chesterfield*.—The Town Council has decided to introduce a railless transport for the town and has recommended an expenditure of £27,548 for the conversion of the tramway overhead equipment and the purchase of 14 trolley vehicles.

(6) *Darlington*.—The Corporation has applied for powers, which if sanctioned, will enable them to replace six miles of existing tramway by trolley buses, together with extension work, providing for a further six miles of service on the same system.

The application Bill has been read for the second time and comparative figures of interest are as follows:—

To relay the tracks and purchase new tramcars would cost £160,000 against a cost of £35,000 for replacing overhead equipment and purchasing trolley buses. The position defined becomes worse if extensions are carried out on the old system, inasmuch that to the £160,000 has to be added £140,000 for laying new extensions, making a total of £300,000, whereas the extension routes for trolley buses

only cost £25,000. Thus including the extensions, the total outlay for tramways would be £300,000 and for trolley buses £60,000. The opening of one section of the new trolley system took place on the 17th January, 1926.

(7) *Hartlepool and West Hartlepool Corporation.*—A somewhat similar position to that outlined in the preceding case prevailed and a decision has been made in favour of the railless system.

(8) *Keighley Corporation.*—This Corporation has the distinction of being the first town to abandon altogether the tramway system originally operated and replace it wholly by railless services. The last tram ran in December 1924. Figures which led to the decision are as follows:—

Original Tramways.

Estimated cost of relaying $2\frac{1}{2}$ miles of worn out track	£30,000
Renewal and maintenance of remainder (per annum)	£ 3,500
Annual cost, including capital charges which could not be met by profits	£ 6,150

Railless Substitution Throughout.

Estimated cost of substitution of railless on whole system of 6·62 miles including new cars	£27,850
Annual capital charge on above	£ 4,038
Profit estimated at (per annum)	£ 2,970

which would be available for meeting charges on old undertaking.

(9) *Wolverhampton* :—The trolley bus has also found much favour here and is being rapidly extended, several hitherto non-paying routes on the old system have been converted into paying ones through the change.

(10) *Finally, the Ministry of Transport return issued in 1925* shows that 13 local authorities and one Company operated trolley omnibus services, whilst 17 local authorities and one Company have obtained powers for operating. The total route length open for traffic was 54·4 miles and powers not yet exercised provide for an additional 113·5 miles. During the year 18,441,102 passengers were carried, an increase of 6,637,655 or 56·2 per cent. The number of miles run increased by 36·6 per cent to 2,188,764, whilst energy consumed amounted to 2,920,947 units, or an average of 1·33 units per car mile.

The list could be still further augmented but it will be self-evident that the trolley bus has come to stay and that in common with other developments of a similar order, the experimental stage

has passed, which however should not be taken to mean that finality has been reached, any more than is the case with the motor bus. Turning to conditions elsewhere, the facilities of trolley bus traction are being taken advantage of to meet an economic situation, similar in attribute to that of Great Britain, in Shanghai, South Africa and New Zealand.

RUNNING AND MAINTENANCE COST ASPECTS.

Now closely associated with the question of capital costs on proposals made, are the unavoidable and ever important elements or running costs and maintenance costs. These items necessarily call for careful examination and as will be readily understood, it is not an easy matter to obtain reliable data thereon. Apart from the aspects of capital expenditure which have proved most effective in bringing about the present development, one of the main arguments put forward in favour of the trolley bus, is its low running cost, as compared with both its greatest competitor the petrol motor bus, and the tramcar. About both however exists a considerable divergence of data and it will be obvious, comparative costs to be of value, must allow for and include, all the local elements called into operation, which admit of reasonable interpolation. For any traction problem worthy of the name, the matter clearly is not so readily solved, as is the question say, of comparing the costs of generating electricity. For example, the running and maintenance costs of suburban electric train service in and around Bombay, necessarily cannot present a similarity of *local elements* to that which exists in Melbourne or Durban. Apart from all other factors, this divergence is bound to reflect itself at some point upon the cost of operation. As related to railless traction, the elements which bear most on running and maintenance costs are :—

(1) The seating capacity and the type of vehicle used.
(2) The schedule speed and the number of stops per mile.
(3) The condition of highway and its gradients.
(4) The price paid for power.

The design and type of vehicle used will be chiefly governed by (1), (2) and (3), which again have a close connection with maintenance. Primarily (1) and (2) will be governed by the traffic conditions. Here it may not be amiss to state, that as related to design, it is remarkable what a uniformity was, and still is to be found in the general lines of British tramcar construction. Anyone who has seriously endeavoured to get improvements effected of provable utility, will therefore know how difficult it was to get the car-builder to make a change, if it involved any radical depar-

ture from pre-conceived standards. This was owing chiefly not so much as may be thought, to the economic equation it presents to production cost, but more directly to an inertia which always resists change of any kind, until forced to yield to it. Following too closely a modified form of tramcar construction, the design of the earliest trolley buses was such as undoubtedly delayed giving proposals for their adoption the same consideration that is given the matter to-day. Paradoxical though it may appear, the advent of the petrol motor bus, the most formidable competitor of the tramcar in suburban and the less densely located transport services brought about a utilisation of the motor-bus designers' services and it cannot be gainsaid, that the present day successful vehicles, giving daily satisfactory service, are largely the result of splendid effort on the part of designers, competent to build both types of vehicle. Photographs are appended which clearly illustrate the trend and scope of the most up to date trolley bus design. Turning now to the question of cost, the following data should prove of utility:—Table I gives some statistics of tramway costs; Table II statistics of Municipal railless services; and Table III some statistics of motor omnibus services. All the tables include localities in common and indicate operating conditions and costs, which to some extent admit of reasonable inferences of comparison for traffic purposes. As a further aid in this respect, the following *averages* based on the figures given and relating to the three types of transport service covered should be useful.

ELECTRIC TRAMWAY SERVICE.

Average revenue per car mile on nine undertakings	=	19·22 d.
,, operating costs per car mile on nine ,,	=	14·53 ,,
,, fare per passenger ,, ,, ,,	=	1·67 ,,

RAILLESS SERVICE.

Average revenue per car mile on twelve undertakings	=	15·19 d.
Average expenses per car mile (including power) on 12 undertakings	=	13·33 ,,
Average fare per passenger on 12 undertakings	=	1·97 ,,

MOTOR OMNIBUS SERVICE.

Average traffic receipts per bus mile on four undertakings	=	16·900 d.
Average expenses per bus mile on four undertakings	=	13·058 ,,
Average fare per passenger on four undertakings	=	2·630 ,,

TABLE I.

SOME STATISTICS OF ELECTRIC TRAMWAY COSTS.

England and Wales for year 1924-25.

Name of Town.	Total capital *expended.	Length of route	Passengers carried	Car miles run	Kelvins or kwh used.	POWER COSTS PER UNIT. Works costs.	Purchase costs.	Revenue per car mile	Total operating costs per car mile.	Average fare per passenger.	Traffic Revenue.
	£	(miles)				(pence)	(pence)	(pence)	(pence)	(pence)	£
Aberdare	224,279	5·77	4,831,318	541,572	893,854	—	1·37 (b)	17·05	12·56	1·91	38,476
Birmingham	3,019,539	71·23	214,338 365	17,521,741	29,371,232	—	1·40 (c)	18·19	12·72	1·49	1,327,870
Bradford	1,422,258	60·28	92,683,421	6,863,348	15,496,787	—	1·52 (c)	21·85	17·66	1·62	624,778
Halifax	538,002	38·89	23,789,656	2,358,080	5,851,503	—	1·50 (c)	22 05	18·05	2·18	216,633
Ipswich*	124,099	9·35	5,922,474	582,729	752,656	—	1·25 (b)	16·67	14·55	1·64	40,470
Keighley	48,677	3·31	4,087 718	246,061	331,935	—	1·50 (b)	19·95	15·43	1·20	20,454
Leeds*	2,108,774	66·68	144,768,459	11,037,938	19,550,783	0·59	0·49	19 78	13·01	1·51	909,898
Wolverhampton	396,272	11·80	14,870,878	1,213,548	1,906,216	—	1·60 (b)	20·00	14·47	1·63	101,131
York	206,350	8·49	7,576,309	817,080	1,482,238	—	1·50 (c)	17·46	12·29	1·88	59,440

Note:—

*These items are for the year ended March 31, 1925.

Under power purchase costs; (b) indicates power supply and capital charges on generating plant

Under power purchase costs; (c) indicates power supply, capital charges on generating plant and tramway feeders

During year 1923-24 Birmingham tramway undertaking contributed £27,000 to the rates.

" " " Bradford " " " 13,000 " "

" " " Halifax " " " 7,053 " "

" " " Leeds " " " 41,910 "

TABLE II.

SOME STATISTICS OF MUNICIPAL RAILLESS SERVICES—GREAT BRITAIN—

For Year 1923-1924.

Name of Town	Capital outlay. (£)	Length of route opened (Miles - ch)	Passengers Carried	Car miles	Total Receipts (£)	Working Expenses (£)	Revenue per car mile (pence)	Expenses per car mile including power (pence)	Average fare per passenger. (pence)	Average fare per mile. (pence)	Average number of cars in service
Aberdare	14,068	1 — 42	249.636	22,758	2,116	1,553	22 32	16·37	2·03	2·86	1
Birmingham	37,220	2 — 35	4,924.898	339,396	25,420	17,183	17·97	12·15	1 24	0·83	10
Bradford	28.584	9 — 39	3,601,004	408.236	20,297	25,447	11 93	14 94	1·35	0·92	9
Halifax	6,390	2 — 33	222,906	36.703	2,767	2,428	18 09	17 49	2·97	1·68	—
*Ipswich	6,129	0 — 50	500,536	38,565	2.111	1,914	13·05	11 92	1·01	1·61	2·32
Keighley	21,519	5 — 70	453,193	73.345	5,851	5,395	18·81	17 65	3·04	1·81	3
Leeds	28,932	8 — 70	2,072.689	316.824	14.235	14,697	10·75	11·13	1·64	0·88	7
Ramsbottom	13,753	3 — 35	749,905	96,919	5,875	5,473	14·38	13·55	1·44	1·74	2·70
Rotherham	12,130	6 — 33	443,741	151,247	5,600	7,218	8·72	11·45	2·97	0·91	4·5
Teeside Railless*	...	...	..	...	...	...		...	—	—	—
Traction Board	83,294	5 — 80	3,023 075	434.793	28,457	23,339	15·67	12·88	2·23	1·07	4
*Wolverhampton	11,372	2 — 20	874,802	93,406	6.239	4,140	16·03	10·64	1·71	1·23	5
York	15,800	1 — 18	433.726	59,448	3.613	2,435	14·56	9·84	1·97	2·00	3

Note:—* (Ipswich) figures shown are from September 2/23 to March 31/24 only.

* (Wolverhampton) figures shown are from October 29/23 to March 31/24 only.

TABLE III.

SOME STATISTICS OF MOTOR OMNIBUS SERVICES—ENGLAND AND WALES—

For Year 1923-1924.

Name of Town.	Capital outlay (£)	Total length or routes served (miles)	Passengers Carried.	Bus mileage.	Traffic receipts per bus mile (pence)	Working expenses per bus mile. (pence)	Average fare per passenger (pence)	Number of vehicles in use.
Aberdare	16,759	6·75	988,384	153,052	16·850	13·430	2·610	7
Birmingham	107,820	40 37	16,524,739	2,179,439	15·595	11·976		78
Halifax	5,022	3·80	439,244	50,595	20 160	16 510	2·320	3
Keighley	3,125	2·74	300.611				3·524	2
Rotherham	8,630	26·86	1,484,348	297,295	13·520	10·900	2·710	16
Wolverhampton	26,943	58·00	3,275,561	607,152	17·071	11·392	2·880	22
York	10,517		661,230	96,638	13·730	9·040		

To those interested Table IV which follows may also be of service and attention is invited to the closeness of the *average* units per car mile shown over the periods taken. True, statistics are often misleading, not infrequently too, of intent, but the checked averages undoubtedly indicate a uniformity of creditable performance on the part of motormen, taken as a whole; which matter incidentally, had no bearing whatever on the selection made.

TABLE IV.

ELECTRIC TRAMWAY UNDERTAKINGS.

Name of Town.	ended March.	Kelvins or kwh used per car mile.	Year ended March.	Kelvin or kwh used per car mile.
Aberdare	1923	1·37	1924	1·65
Birmingham	,,	1·86	,,	1·68
Bradford	,,	2·24	,,	2·26
Halifax	,,	2·41	,,	2·48
Ipswich	,,	1·33	1925	1·29
Keighley	,,	1·35	1924	1·35
Leeds	,,	1·77	—	—
Wolverhampton	,,	1·57	1924	1·57
York	,,	1·68	..	1·81

Note :—The average units taken on eight undertakings shown for 1923 = 1·73 per car mile

,, ,, ,, ,, ,, 1924-25 = 1·76 ,, ,, ,,

Special Note :—The 1924 return for " Railless " services shows an average of 1·33 units per car mile, taken over the whole systems in operation.

It follows from what has gone before, that whereas the comparison figures are of little or no technical value, that being outside the function of the tables, they nevertheless do present exceedingly useful information regarding traffic and its relation to the all-important financial aspect. The latest available data on operating cost are as follows :—

Period.	Name of Town.	Type of Vehicle.	Operating costs per car mile.
1925	Birmingham	Petrol motor buses (D.D.)	13·00 d.
,,	,,	Tramcars	12·59 ,,
,,	,,	Railless (D.D.)	12·06 ,,
,,	West Hartlepool	Petrol motor buses	13·00 ,,
,,	,,	Tramcars	18·49 ,,
,,	,,	Railless	10·59 ,,
,,	York	Tramcars	13·81 ,,
,,	,,	Railless (S.D.)	12·68 ,,
,,	Teeside Railless Bd.	Railless	12·05 ,,

Checked in another form, the Tramways Manager (Mr. C. O. Silvers) of Wolverhampton Corporation, states the *total* costs per 100 *seat miles* for the three types of transport are as follows :—

Motor buses	= 44·56 d.
Tramways	= 39·56 ,,
Railless	= 37·34 ,,

At Keighley, a check on the running cost for petrol per car mile on the motor bus =2·99d. as compared with the cost of 1·93d. for electricity on the railless system. Turning to maintenance, the City Treasurer (Mr. F. Ogden Whiteley) for Bradford, states the cost of maintaining railless cars is considerably heavier than in the case of tramcars. On the average of the last five years, the Corporation railless cars have cost £472 per annum each to maintain, while the tramcar costs only £359 per annum. Local conditions of course may have a great bearing on this point. Through the courtesy of the General Manager (Mr. R. H. Wilkinson) of the Bradford Corporation Tramways, I am enabled to place before you the following comparative statement excerpts of

average cost per car mile, of tramways and railless, for the year ended 31st March, 1925:—

Traffic Expenses.

Tramways	= 7·486d.	
Railless		6·471d.

General Expenses.

Tramways	= 1·671d.	
Railless		1·060d.

Repairs and Maintenance.

Tramways	= 1·926d.	
Railless	=	3·960d.
	11·083d.	11·491d.

Under the last sub-head, the item "permanent way" absorbed 1·393d. on the tramways against nil on the railless, on the other hand, the item "cars" shows a debit of 3·427d. under railless, against a debit of 2·609d. under tramways.

The figures relate to :—	Tramways	Railless
Route miles ...	59·007	9·488
Car miles run ..	2,186,002	148,750
Average car miles run per route mile	37,046	15,667

FACILITIES AND LIMITATIONS.

The rapid development of self-propelled or power-driven vehicles during the last two decades, has led to an unprecedented utilisation of such traffic facilities. This advancement of mechanical art has compelled the modern highways engineer to realize, that roads and vehicles must be studied with as deep a comprehension of their economic aspect and the necessity for foresight, as the building of a railway demands, if vast sums of money are to be spent wisely and ability to prove efficiency in a public utility service second to none, is to be demonstrated. One outcome of this state of affairs is a definite recognition on the part of responsible authorities, that while the problems of surface *traffic congestion* call for no constructional technique in the spectacular sense, the two problems are nevertheless so intimately related in the final

results obtainable, that no town planning schemes, street widening projects, or regulations for the betterment of transport facilities, can afford to ignore their proper co-ordination. In addition, the costs of street and road maintenance have attained an importance of undreamt of significance to the rate-payer and tax-payer. Contrary to expectations, neither the total elimination, where possible, of slow moving vehicular traffic, nor yet the tremendous reduction effected thereunder, as the result of higher speed mechanically propelled vehicle substitution, has sufficed to bring about the desirable state of affairs many had hoped would follow therefrom; on the contrary, the difficulties experienced have provably increased, by reason of the highways being called upon to carry more and more vehicles, having dimensions, weights and speeds of every conceivable order. The extent of this aspect may be judged from the following figures taken from London statistics 1923-24.

PASSENGER JOURNEYS IN GREATER LONDON.

Year.	Millions of Passengers carried. (Railway traffic excluded.)			Estimated population of Greater London.	Journeys per head of population. (Railway traffic excluded.)		
	Tramway	Omnibus.	Total		Tramway	Omnibus.	Total.
1903	394	287	681	6,726,000	58	43	101
1913	812	736	1,548	7,353,000	110	100	210
1923	1035	1214	2,249	7,625,161	136	159	295

Factors of obstruction are therefore of ever increasing importance and the tramcar which operates in narrow streets or highways, labours under two disadvantages coming under this head. In the first place, all stops in general are made at points where passengers either getting on or off, have no option but the one of crossing a street or high-way, with at times its undoubted attendant risks; in the second place, the failure of supply on a route section is productive of congestion, owing to its usually occurring at a time, which causes a long line of cars to be held up. Like the motor bus, the trolley bus operates in such a manner, that it can pull up at the kerbside, the most desirable point to either get on or off, wherever desired on the line of route and should a failure of the supply occur, it does not necessarily imply an undesirable if but

temporary, monopoly of that part of a thoroughfare, which free fast moving traffic equally claims a right to use. At the same time it should not be overlooked that for dealing rapidly with *dense traffic*, no existing system of *street surface* transport affords the same facilities as does a well organized and properly maintained tramcar system, nor can it do so at less cost with the same relative advantages. Technical aspects outside the scope of this paper and chiefly associated with the mechanical ability of the tramcar to operate under conditions of greater overload capacity than any other road vehicle, plus the advantages derived from the use of two motors under series parallel control largely contribute to this end. True, motor bus competition in Glasgow has resulted in an estimated loss to the tramcar system of £100,000 per annum and legislative powers are even being sought in Greater London tending to limit competitive conditions, where the tied to track conditions are found running at a loss, but that there still exists a field for both free and tied to track traffic, cannot be doubted. A good example of the excellent facilities afforded by the now oft-looked down upon tramcar is to be found in traffic figures for the Metropolis of London during 1918, wherein it was shown that *each* motor omnibus ran 37,500 miles and carried 363,000 passengers, while each tramcar ran 39,000 miles and carried 515,000 passengers. It is now possible to make a comparison of the relative advantages and disadvantages of the three systems of passenger transport which have called for consideration, in order that the claims of "railless" can be properly presented.

Financial Aspect.

On the capital expenditure side, the petrol motor omnibus system shows to the greatest advantage, inasmuch that such expenditure more readily admits of accommodation to a variable factor of utility than does the tramway or railless system. In the latter case, capital expenditure on a permanent rail track is eliminated, together with its incidental maintenance, but expenditure on the overhead line work is increased, by reason of a double conductor system being required. Depreciation is higher in the case of the motor omnibus and *excepting for tyres*, lowest in the case of the railless vehicle. If, however, tyres are included, then granted normal conditions, depreciation at present is higher in the case of "railless" than for the tramcar.

Revenue-earning Capacity.

From the data presented it will be clear, the most important elements from a traffic point of view, will be the elements of

capacity, flexibility and service reliability. The conditions of service called for will normally govern capacity and the tramway here easily comes first by the nature of the case. The petrol motor omnibus and railless bus being so allied to each other in constructional design, leaves little or no element of great divergence between them where capacity is concerned, since both types admit of being built up as required, either as single deck or double deck, low loading vehicles. Flexibility is an element which may be relative or not, according to the point of treatment. Thus, where conditions permit of entering a tramcar at a specially constructed covered street crossing stop and travelling right up to a railway terminal point, the same degree of flexibility would be attributed b. many, as that applicable to a petrol motor omnibus doing the same thing, with the exception that the latter carries passengers to the kerbside. Under certain traffic conditions, the *tramcar* too, may even reach the terminus first, since *vehicle* flexibility is by no means the same thing as *route* flexibility. Treated in its generally accepted sense, however, the tramcar is tied to both track and overhead route, even as the railless bus is tied to the latter only and therefore the petrol motor omnibus possesses the greater degree of flexibility, from the point of view that it is a complete, self-contained, propelling unit, limited only to the routes and highways along which it is licensed for service. Nevertheless despite its being confined to a route, which is limited by the distance to which an electric supply feeder can deliver energy sufficient to maintain the necessary pressure to operate trolley buses from an overhead trolley system, the trolley bus having a range of not less than thirty five feet within which to manipulate at will, in and among other highway traffic, possesses on such a route, an equal degree of service flexibility. As a revenue earning proposition, the petrol motor omnibus, with its greater elasticity of movement at road crossings and ability to travel wherever licensed, between points where distance cannot present the same limiting factors* that it does in the case of the other systems, has not only in many places compelled tramway authorities to adopt it themselves as a subsidiary to the tramway proper, but it has also diverted considerable traffic *off* the local railway systems. Now speed of transit is a positive determinant in traffic problems and in this element,

*Note:—Messrs. Tilling-Stevens, the well-known producers of the petrol electric bus, have had a type of petrol electric trolley bus in operation for some time. This vehicle is built to operate either as a trolley-bus, or on the Tilling-Stevens petrol-electric principle. The combination enables the vehicle to be used for long distance running, it therefore possesses all the flexibility of the petrol bus, with the advantages of the railless, for use on routes which call for such a service.

" railless " shows to the greatest advantage over the petrol vehicle. Factors of the element in question are:—

(1) Ability to get away and pull up in a minimum of time; i.e., rapid acceleration and deceleration, supplemented by easy control under congested traffic conditions.

(2) High average speed regardless of gradients.

(3) High overload capacity.

These factors moreover, have a definite relation to the comfort of the passengers carried, which cannot be ignored and here again, the "railless" system, using pneumatic tyred, well sprung vehicles, compares most favourably, since it demonstrates them to a high degree; in addition, no one who has had the experience, can fail to comment most favourably on the absence of noise and vibration afforded by " railless " as compared with the petrol motor omnibus. There being no changing of gears or other disturbing elements which abuse the sense of "hearing" to the same degree, nor yet the emission of noxious fumes which abuse the sense of " smell," it also follows, the extension of " railless " has proved popular wherever it has been adopted, which statement is not to be taken as lacking in respect for the builders and operators of the petrol bus. Having reference to the factor of reliability the figures of mileage and cost already given, show that each type of vehicle possesses reliability to a high degree and it cannot be doubted, the successful manner in which passenger transport services operate as a whole, under variable conditions of service and climate, prove that both the builders and operators of vehicles, recognize the great importance of paying special attention to this point. Summarised briefly, the case for " railless " traction is clearly established as being in every way advantageous to the public, wherever traffic conditions call for improved transport facilities, but the capital cost of a tramway proper is prohibitive. Secondly, where a tramway system already exists and successful development works are proceeding, an obvious duty of the tramway authority is one of examining the conditions, with a view to extending its overhead system for railless service into suitable districts, serving as feeders to the main system. With either case in question, the electric supply authorities exist to obtain a greatly enhanced revenue and the general public a greater demonstration of the utilitarian advantages presented by the advancement of the mechanical arts.

CONCLUSION.

Turning now to India, it cannot be too clearly recognized that despite many obstructive elements which are often erroneously attributed to so-called political ideals, or even to beliefs of another order, the wheels of progressive effort cannot be arrested. Sooner or later and the signs of the times are, that it cannot be postponed over-long, India will either be compelled to take up a far greater position of enterprise in the world's work, or pay the inevitable penalty which follows a continuance of lethargy and indifference to the higher welfare of its millions. As the standards of living change in an upward sense, with the diminution of illiteracy, even so does the tendency for a greater development of industrial effort make itself felt. Such expansion is invariably productive of density increases in area population and it cannot be doubted, apart from all other considerations, the provision of cheap and rapid transport facilities, forms one of the greatest assets in everyday life. As related to the subject of "railless" and quite distinct from the efforts of private enterprise in connection with electric supply undertakings, the gradual electrification of the railways either proceeding or projected, should bring about conditions tending to call for increased highway and local subsidiary transport facilities at many undeveloped points. If, with all due regard to the commercial aspect, as can be shown elsewhere, its development gives an impetus to the upliftment of communal life, no avenue of expansion should be ignored. Excluding the great railways and associated with a few of the leading cities, the highway transport field of India is yet but little developed and little or no co-ordination of effort to recognize its importance as a means of relieving housing congestion in industrial areas, or as an aid to successful industrial effort, or even as an indication that pedestrian traffic merits the consideration found elsewhere, can be proved to exist, between the various authorities having the powers necessary for stimulating such development. It is true such developments call for much money, but I venture to think the greater need is spade work of an educational order, and such labour is held to rest on a far higher basis than does the too common one of endeavouring to effect economies, more often than not, provably retrogressive and non-productive in character.

In conclusion, I desire to place on record, my sincere thanks for courtesies and facilities extended to me in particular by, Messrs. Alfred and A. C. Baker, respectively General Manager and Chief Engineer of the Birmingham Corporation Tramways; to Mr. R. H. Wilkinson, General Manager of the Tramways Dept., Bradford; to Messrs. Railless, Ltd., of London; to Messrs. Richard

Garrett and Sons of Ipswich. For useful data I am also much indebted to :—

Montague H. Cox Esquire.

The Clerk of the Council, London County Council.

The Proprietors of the Municipal Journal, Ltd.

The Proprietors of the Electric Vehicle.

The Proprietors of the Electrical Times and others.

Your attention is furthermore directed to :—

(1) Fig. 1. which illustrates how good acceleration is obtained from a type of motor specially designed for "railless" service. The curves relate to a motor built by Messrs. Bull Brothers, Ltd., of Ipswich, and cover a ventilated type motor—one hour rated—for 50 H.-P., at 1060 R.P.M. It is built in accordance with the B. E. S. A. specification No. 173 of 1923. The commutation is absolutely sparkless at any load up to 250 amperes with 33% field diversion.

(2) Appendices Nos. 1 and 2 show tramway statistics illustrating the extent to which surface transport traffic has developed in localities far apart and operating under entirely different local conditions.

(3) Appendix No. 3 gives particulars of railless vehicles in use at Bradford.

(4) Appendix No. 4 gives vehicle weight comparisons.

(5) Appendix No. 5 gives the leading dimensions of a Garrett trolley 'bus.

(6) The three photographs illustrate :—

(a) Two Types of trolley 'buses in service.

(b) Constructional details of a Garrett trolley 'bus chassis.

APPENDIX No. I.

LONDON COUNTY COUNCIL TRAMWAYS

Miscellaneous Statistics Year 1923-24.

Net capital expenditure to 31st March	£15,777,710	Units of electricity used	139,051,301
Car miles run	64,118,565	Cost per unit of units used for traction	0·988d.
		No. of cars in stock :—	
Passengers carried :—		Electric bogie cars	1,501
Total	689,015,086	,, single truck cars	301
Per Car mile	10·75	,, steel subway cars	50
Total revenue	£4,374,057	Trailer cars	158
Passenger traffic revenue	£4,285,761	Horse cars	2
Average fare paid per passenger	1·49d.	Length of Line :—	
Average receipts per car mile	16·37d.	L. C. C. tramway tracks	
Average car miles per day per car	124·64	conduit system—miles	122·53
Average car hours per day	13·95	overhead ,, ,,	32·79
Average number of cars in use :—		Total	155·32
Ordinary	1,445	Leyton U. D. C. Tramways tracks	
Trailer	17	overhead system—miles	8·82
Average speed per hour (miles)	9·49	Grand Total—miles	164·14

NOTE :—For Tramways and Omnibuses combined, the year 1922-23 recorded an increase of 20·4 per cent in Passengers carried and an increase of 24.6 per cent in Car miles run.

APPENDIX No. II.

SOME STATISTICS OF THE BOMBAY ELECTRIC SUPPLY AND TRAMWAYS COMPANY.

Showing the extent to which the prevailing trade depression in and around Bombay reflects itself upon the tramway traffic returns, despite the fact, that the majority of revenue obtained, is dependent upon fares charged under conditions fixed as far back as the year 1905.

Year ended.	Route miles.	Car miles run.	Passengers carried.
31st December 1909	20·38	—	32,210,468
,, ,, 1919	22·33	—	72,596,409
,, ,, 1923	26·85	6,056,734	101,995,572
,, ,, 1925	,, ,,	5,482,140	96,321,140

Census population for year 1921 numbered 1,175,914

Estimated ,, ,, ,, 1924 (June) was 1,239,767

APPENDIX No. III.

BRADFORD CORPORATION TRAMWAYS.

Particulars of Railless Vehicles.

	ONE MAN SINGLE DECK.	DOUBLE DECK CAR No. 521.	DOUBLE DECK SIX WHEEL CAR No. 522.
DATE INTO SERVICE.	Jan. 1923	Nov. 1920.	April 1922.
Weight—	T. C. Q.	T. C. Q	T. C. Q.
Weight on front wheels (unloaded)	2 5 3	2 11 3	3 16 2
,, ,, rear ,, ,, ...	2 19 2	4 17 0	3 18 2
Total Weight	5 5 1	7 8 3	7 15 0
Height—	Ft. In	Ft In.	Ft. In.
Clear height—lower saloon	6 3½	6 0	5 10
,, ,, top ,, ...	..	5 6	5 6
Height over roof of car	9 6	15 4	14 7
,, to top of trolley standard .	11 10	16 4	15 7
,, of chassis above roadway	2 8	2 11	2 6
,, of floor from roadway	3 0	3 4	2 8
,, of platform from roadway ..	3 0	2 3½	1 10½
Length—			
Length of vestibule	3 9	4 0	4 0
,, of body	17 5½	13 6	14 5
,, of platform	..	4 6	4 5
Overall Length	21 2½	23 1	23 10
Width—			
Extreme width over mudguards	7 6	7 10	7 6
Bottom saloon—outside width	6 10	6 10	6 10
,, ,, inside ,, ...	6 6	6 4¾	6 5
Roof ,, —outside ,, ...	...	5 10	6 3
Upper saloon —lower portion	...	6 5½	6 10
Gangways	1 1	1 5 lower 1 1 upper	1 5
Doorway	2 2	1 8	1 3

APPENDIX No. III—*contd.*

	"ONE MAN" SINGLE DECK	DOUBLE DECK CAR No 5.1.	DOUBLE DECK SIX WHEEL CAR No. 522
Wheels—			Front Rear
Wheel Base	14 0	13 0	15′ 10″ 11′ 9″
,, track	6 6	6 7½	6 6 6 7½
Tyres—solid	F 120×850×1008=39⅝″ R. 120×850×1008	F. 130×771×933 =36·73″ R. 140×850×1013 =39·88″	F. 120×771×929 =36½″ R. 120×850×1008 =39⅝″
Seating capacity—			
Lower saloon	30	25	26
Upper ,, ...	...	26	33
Total seating capacity	30	51	59
Size of seats	2′6″ lg.×12″ w.	2′8″ lg.×12″ w.	2′8″ lg.×12″ w.
Interspace between seats	1′ 2″	1′2″	1′2″ b. 1′1″ top.
Brakes—Number and types	Two drum and rear wheel	3 Rheostatic Countershaft and rear wheel.	3 Countershaft Front wheel and rear wheel.
Motors—Number and types	One 45 H.-P. traction.	One 45 H.-P. traction.	One 70 H.-P. traction.
Driving mechanism	Differential with worm wheel and driving axles	Double reduction. Gear and chain 4·97 to 1	Gear and chain. Reduction 10·5 to 1.
Speed	Max. speed on level 20 m.p.h.	9½ m.p.h. a.m. 7½ ,, p.m. Max. on level 18 m.p.h.	Max. speed on level 19 m.p.h.
Electrical consumption	1·2 u p c m (est)	1·5 u p c m	1·5 u p c m (est.)
Miles run to October 31st, 1925	Tot. miles 6 cars 539,220 Car Av. 89.870	Tot. miles 173,274	Tot. miles 117,351
Centre of Gravity—			
Height of centre of gravity from road—			
—empty car	4′ 3″ est.	4′ 10″ actual.	4′ 6″
—loaded	4′ 4½″	...	...
—bottom deck full only	...	5′ 0⅝″	4′ 9½″
—top ,, ,, ,, ...	...	6′ 1 3/16″	5′ 10¼″
—both decks full	...	6′ 0⅛″	5′ 9½″

APPENDIX No. IV.

* Comparison of Weights per Passenger carried by Transport Vehicles.

Petrol bus, single deck, average weight per seat.	= 296 lbs.
„ „ double „ „ „ „	= 256 „
Trolley-bus, single deck „ „ „ „	= 355 „
„ „ double „ „ „ „ „	= 297 „
Tramcars, single deck , „ „ „	= 896 „
„ double „ „ „ „ „	= 440 „

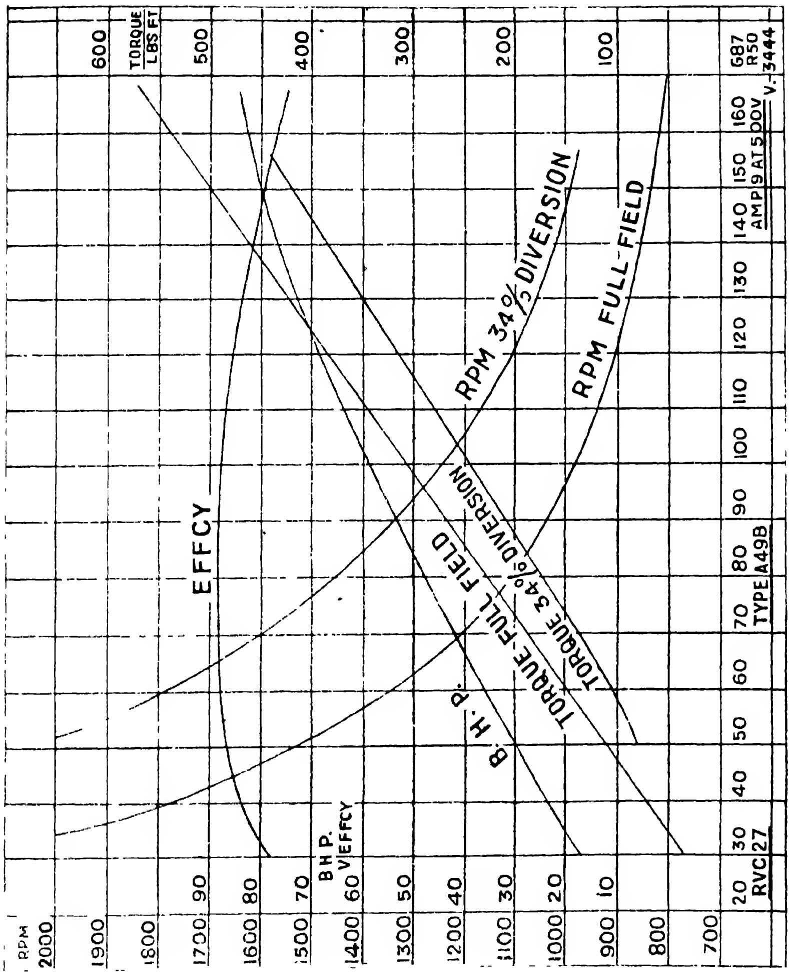
* Abstract from paper of Mr. E. M Munro read before the Congress of Tramways and Light Railways Association, Bournemouth.

APPENDIX No. V.

LEADING DIMENSIONS OF A GARRETT "S" TYPE TROLLEY BUS.

Overall length of Bus	26 ft. 0 in.
Overall width of Bus	7 ft. 6 in.
Width of Body	7 ft. 4 in.
Height of Body from Floor Level to under Roof Sticks	6 ft. 2 in.
Seating Capacity	37 Passengers.
Width of Passenger Entrance	4 ft. 0 in.
Wheel Base	15 ft. 6 in.
Wheel Track	6 ft. 4 in.
Size of Brake Drums	24 in. diameter, 7 in. width
Size of Tyres (when solids are fitted)	Front single 160 mm for 850 mm Rim.
	Rear Twin 140 mm for 850 mm Rim.
Approximate weight, complete with Body	5 Tons.

Fig. 1



Speed Curve for 50 H.P. Bull Motor Showing that the Torque does not drop off Rapidly at the Higher Speeds.

STANTON ON RAILLESS TROLLEY SYSTEM.

DISCUSSION ON
RAILLESS OR TRACKLESS TROLLEY SYSTEM

The Chairman in opening the discussion congratulated the Author on his interesting and instructive paper and remarked that his investigation into the statistics of so many tramway undertakings must have involved, in itself alone, very many hours of work. If railless traction were in any way to displace the existing track system in Calcutta it could only be done in small sections to start with, such as, possibly, over the new Howrah Bridge to connect the tramways on the Calcutta bank with those on the Howrah bank of the Hooghly. Consideration of the running of tramways over the new Howrah Bridge is being duly given, but there are some difficulties to be got over in the way of the flexure joints of a floating structure. With a fixed tramway track should a bullock cart break down athwart it a whole line of traffic is held up by the tram rendered stationary, whereas a railless bus could sweep round the obstruction and not block the traffic behind, and this is a very material matter for people crossing the Howrah Bridge to catch a train at Howrah Station. On the other hand there would be the incovenience of passengers having to change from tramway into trolley-bus on one side of the river and afterwards from the trolley-bus into tram on the other side. It was of considerable importance to the Members of the Institution that Mr. Dain of the Calcutta Tramway Company was present in the audience, and it would be of interest if Mr. Dain could give us some information regarding the life of tramway track under conditions obtaining in an Eastern town like Calcutta. According to the Author's figures the cost of the tramway track at Keighley worked out to something in the neighbourhood of Rs. 33 per running foot and it woull be of interest to know how that compares with the cost in Calcutta. It was worth noting the remarkably good estimating of the possible trolley-bus receipts in the case of the Birmingham Corporation, their estimate being £28,300, and the actuals £27,845. Apparently receipts come in most cases to about an all-round average of 1s. 6d. per mile. One of the advantages of the Author's Paper has been the bringing to light to members of our Institution the fact that the railless trolley-bus system has now been in use for a greater number of years than many of us would have thought; and in a good many places too; and that as long as 16 years ago the system was adopted by the Bradford Corporation.

The cost of a railless route apparently hovers between one-fifth and one-sixth of the cost of new tramway track, and the energy consumed works out at an average of about 1·83 units per trolley-bus mile. This figure would be of interest to Mr. Dain as a comparison with his Calcutta tramway costs.

On page 6 of the Paper Interest and Sinking Fund charges on the total capital cost of the three different systems are given. In the case of Tramways this works out at $8\frac{1}{3}$%, in the case of the railless at 10%, and in the case of ordinary buses at nearly 16% of the capital cost. In the case of the annual capital charge of the railless system at Keighley this apparently works out at $14\frac{1}{2}$%. It is rather difficult to reconcile these differing percentages. The Author comments upon the constant difficulty there always is in effecting any change involving a radical departure from existing standards. Calcutta, however has taken on a new lease of life during the past two years, as evidence by its numerous buses and judging by their multifarious designs.

An interesting point brought out in the Author's statistics is that for every unit of 100 seat miles the railless system is the cheapest of all three systems. From the statistics of passenger journeys in London it would appear that bus traffic now predominates but the Chairman rather agreed with the Author that there probably existed a field for both free and tied-to-track traffic, and that this was the broad and probably the most correct view to take. If a trolley-bus has a range of some 35 ft. within which to manipulate is there not considerable likelihood of a bad driver disconnecting the trolley arm from the overhead wiring? Presumably however this is simply a matter of experience. Unquestionably the absence of noise and vibration and of the smell of fumes are distinct adjuncts to a railless trolley system.

A point of pathetic interest to note from the statistics given by the Author regarding the London County Council tramways is the fact that out of 2,012 cars in service in 1923-24 only two of these were horse drawn. Probably to-day even these may no longer exist.

Colonel Sir Gordon Hearn said, in view of the author's statement on page 52 that "no existing system of street surface transport affords the same facilities as does a well organised and properly maintained tram car system, nor can it do so at less cost with the same relative advantages" he felt supported in his opinion that tramways have not of recent years had a "square deal". The British temperament approves of unlimited competition and perhaps rightly so, but it is a grave question whether recently the tramways have not been unfairly handicapped.

Originally welcomed, long before the petrol driven bus appeared, tramways were made to keep up a considerable area of

that road surface, which the drivers of cars, owners of buses, and the public now exploit to the utmost, resenting the right of way once given to the tram car. No doubt the fact that the tram car does not draw up at the pavement and therefore both passengers and road traffic are temporarily incommoded, has a good deal to do with the prejudice against tramways, a prejudice which the author's remarks show to be unreasonable. It is surprising to find what an increase in tramway journeys per head has taken place in Greater London, in the last ten year period given on p. 51, in spite of the great competition of motor buses. Tramways therefore are providing for a real need and it is unfortunate that co-ordination of transport facilities by traffic authorities is so neglected. It was for this co-ordination that the London General Omnibus Company in 1924 conceded some of the demands of their employees, but has this advantage materialised? A recent endeavour to restrict certain buses from overcrowding a certain route ended in failure when the last case came before the Magistrate.

A good deal is said about tramways being worked at a loss and as a charge on the rates, but probably this loss is offset by the local authority being at less expense in scavenging in the central areas, while the wider distribution of houses adds to the rateable capacity. Or again the workers may live in the areas of other authorities, and many expenses fall on them—so that the loss may really be a matter of allocation only.

The encouragement given to motor buses by the public has to be paid for, and possibly the local authority has not looked with disfavour at private enterprise finding the capital, which otherwise would have had to be spent on more tram cars. Again the "travel habit" must be good for the tramways. But when the question of scrapping the tramways arises, no fund has been formed for that purpose, and private tramways have vested interests, which experience shows are usually to be acquired only at a high figure. Therefore, the suggestion to use the overhead equipment, modified though it may have to be, with railless buses is an interesting one. At the same time the figures on page 44 seem to show that railless service does not compare well with motor buses, and in particular the fares charged, or at least realised, seem to show a considerable difference. Yet many of the systems are operated side by side, or in the same city. The capital outlay per mile seems heavily in favour of the motor bus, at Wolverhampton for instance.

The impressions left are that there has not been sufficient time to "try out" the railless system and that profits at present are not sufficient to find a depreciation and sinking fund on both new

and old equipment, if the latter, except the overhead trolley wires, is to be scrapped without resorting to confiscation.

The author is to be congratulated on the industry with which he has accumulated figures, which ought to be of great use in calculating financial prospects.

Mr. W. A. Buyers said, the principles enunciated in the paper by Mr. A. Lennox Stanton on the subject of the Railless or Trackless Trolley System must by the very nature of the conditions prevailing in India be limited in application. The number of towns where electric tramways are operated can almost be counted on one's fingers.

In all other large urban areas it is astonishing to see the development of passenger transport by means of the motor bus. This, by first cost, maintenance and overhead charges, being cheaper than is possible in European countries, puts the motor bus in a favourable position to compete with other forms of road transport.

It is therefore open to much serious thought when civic authorities are considering the development of urban traffic, whether such progress should not be in the direction of more motor busses and eschew the attractions of an electrified system.

One has only to see what has happened in the urban and sub-urban areas of Greater London where, *inter alia*, the development of motor bus services depleted the revenues of the London County Council trams, so that they have to be run at a loss, to realise the great responsibility which tram services undertake in competition with more flexible forms of transport. This leads one to the consideration, where to my mind the Trackless Trolley System can function in the most suitable form, and that is in freeing the congested areas in towns, which congestion in sometimes wholly due to the location of tramways in narrow streets.

A most glaring example of what tramways can do in blocking and holding up road traffic for long periods is to be seen daily in the Strand Road in Calcutta. This important artery, which deals with traffic crossing the river to the Railway termini and goods sheds, as well as taking the heavy flow of traffic from the warehouses along the river, is, generally between the hours of 10 A.M. to 6 P.M., almost impassable and it is a common sight to see strings of Tramcars held up along the street from the important junction with Harrison Road. Now these two tracks of tramway must occupy very nearly ⅔rds of the total roadway which explains the cause of most of the congestion in this area. The introduction of

the Trackless Trolley System say from the High Court Terminus to Chitpur and the Harrison Road Branch would go far to relieve a congestion which at present is nothing short of scandalous.

I was very interested to notice on my passing through Ipswich last year the drastic change over which the tramways had made from rail to trackless. The Corporation had evidently not thought it worth their while to take up the rail tracks, which were left in the streets, let us hope, as a silent witness of days of useful endeavour.

In comparing the statistics of cost in Tables I and II for the town of Ipswich, it would appear that the figures are in favour of the Electric Tramway as against the Railless Service. The net revenue per car mile seems to be distinctly in favour of the Electric Tramway and does not support the Author's contention in favour of the Railless Service.

Mr. Atkins remarked that the paper was a very valuable one and especially interesting to him as the possibilities of the railless tram system were considered by the Calcutta Improvement Trust nearly 10 years ago. An important question raised by Mr. Dain was whether it was practically and economically possible to introduce a length of railless service with its positive and negative overhead wires in a narrow congested street such as Chitpore Road without interfering unduly with the existing electric supply arrangements in adjoining routes.

It was the policy of the Improvement Trust to provide separate tracks for tramways wherever possible, and not to allow trams to be laid down in any street which had a width of less than 54-ft. between kerbs. The greatest drawback of the ordinary tramway tracks was its noisiness which so far as present experience went could be overcome only by laying the rails on sleepers instead of on the usual concrete bed. It seemed to him that the absence of noise was one of the greatest assets of the railless system, and that its future success might be largely dependent on whether it was or was not found possible to eliminate noise from the older system.

It had been suggested by the recent Committee on Calcutta Tramways that the railless system might be adopted in one of the new Improvement Trust roads knows as the "Manicktolla Spur." He disagreed entirely with this suggestion as the roadway in question was 54-ft. wide and he understood from figures given in the paper that this would necessitate white lines being laid down along each side of the route to enable the drivers to keep within reach of the trolley wires.

Mr. K. R. Godbole said, I wish to make a few remarks with reference to this paper. I am sorry that the author is not present

to give us further information on the points that will arise during the discussion. I presume however, that the other Electrical Engineers present to-day will be able to help in solving queries that may be raised.

All large towns require cheap and regularly established intercommunication between their different portions and the surrounding suburbs. Accordingly we find the larger cities in India and in European countries equipped with systems of tramways which are fairly remunerative concerns.

In the Bombay Presidency, we have the cities of Bombay and Karachi in which tramways have been well established and are profitable undertakings. But we have cities like Poona and Ahmedabad which require consideration. I am well acquainted with conditions in Poona. We have here a population of about 2 lacs of people with population centres at Kirkee, Wanavadi, Ghorpadi, Yerawada, Bhamburda and Poona Cantonment, etc., situated all round. All these outlying places have a considerable population who have occasion to visit the city, public offices, courts, Railway station and bazars very often during the day. For this traffic, some system of tramways is required. The city receives over 3,000 passengers every day from the G. I. P. and Madras and S. M. Railways and sends out a similar number of passengers by these Railways daily. The component population centres are situated at considerable distances from each other. The surrounding villages also bring about 700 or 800 head loads of field produce, etc., every day into the town. There are 710 two wheeled, 106 four wheeled and 171 bullock Conveyances licensed for hire, which deal with the passenger traffic in the city in addition to 75 licensed motor cars and 146 licensed motor lorries. The motor cars and motor lorries deal with traffic in the Districts. The conveyances plying for hire in the City are 987 and it is estimated that the amount they earn per day is not less than Rs. 3,000 which means an annual income of Rs. 10 or 12 lacs. The Railways bring in and take out also, a large daily parcels and goods traffic.

I think a city like this requires a tramway system. Track tramways on rails may prove to be unsuitable as they are expensive and as they require wide roads, while some of the roads in the city are less than 20 ft. in width. It seems to me that the railless trolley-bus system referred to in the paper is a system that will answer the purposes of Poona very well. The points in its favour at Poona are:—

(1) There is an Electric supply company in Poona which will be glad to secure the day load of tramways and

which will probably be prepared to sell power at 1½ annas per unit.

(2) The trackless trolly bus lines can run in the narrow streets of the city as well as on broad roads outside, without any inconvenience to other traffic, especially as the busses are said to be capable of swerving on the road surface to the extent of 35ft.

(3) There being no rails and no rail track, the cost of construction and maintenance will be very moderate. This will enable low fares to be charged which will kill competition by petrol motor busses.

Judging by the figures of cost in England, as given in Table II on page 16 of Mr. Lennox Stanton's paper, the cost of construction of trackless trolly bus line ought to be in the neighbourhood of Rs. 45,000 per mile which is fairly cheap.

I should like to listen to the views of the Members here on the contents of the paper. Will the trackless trolly bus system suit Indian cities like Poona and Ahmedabad with their narrow roads, and will the installations in these cities be paying propositions in these days? The petrol motor bus will be a powerful competitor and must be kept out of the field by the new tramways being able to charge very low fares. The Capital and maintenance costs of tramways must be low.

Mr. C. V. Krishnaswami Chetty said, I write to inform you that at this moment I forget what exactly I spoke on Mr. Lennox Stanton's Paper. But as far as my memory goes, I remember to have drawn the attention of the author to the monorail system, which was not referred to in his paper. The monorail system is more or less a semi trackless system. The carriages run on only one rail laid close to one edge of the road. Each carriage is provided with two steel wheels one in front of the other fixed fairly close to the longitudinal axis of the chassis. There is yet a third wheel which is of wood with iron rim fixed to the side of the carriage. This is more or less a balance wheel and runs on the road. The rails are only of 18 pounds section and cost comparatively very little. Such a system was working over a distance of about 12 miles between Poonamalli and Avadi not far from Madras. But the system proved a failure not for any technical reasons, but for want of sufficient goods traffic.

Mr. R. K. Nariman **said, I am afraid I am not quite sure now, of what I said. But I believe I suggested that for big cities like Bombay, Poona, etc., which had electric installations, a system of**

busses worked by electric storage batteries may be considered. The batteries could be charged during periods of low demand and thus help to equalize the load factor. It would also reduce the capital and recurring charges as there would be no need to erect and maintain the overhead wires. Such busses are running in Italy and other countries. As regards the fear of damage to roads, because of the heavy weight of such busses, it was expected that the new reinforced concrete roads in Bombay would be found to be strong enough to stand this traffic. Moreover the weight intensity could be reduced by using twin tyres. Perhaps, if necessary, the weight of the batteries may be reduced by reducing its capacity to a few hours only and changing the battery twice a day as it ran down.

Mr. R. D. V. Simham said, the subject taken up by Mr. Stanton is one that will not only tax an Engineer's ability and knowledge of matters pertaining to technical practice, but will require of him skill and knowledge, in the solution of business problems of the greatest importance, in understanding their financial position, the meaning of the items on the balonce sheet and income statement, and in grasping generally the manner in which transportation services and other public utilities should be conducted. In his paper, Mr. Stanton aims at presenting transportation problems, on a business, economic and scientific basis. Much credit is due to him for setting forth so clearly, from a business point of view, the factors that go to decide in favour of the railless system, based on the circumstances of the cases quoted by him from Great Britain. The statistics and particulars gathered by him with regard to the three important services in operation there, his review and comparison of the services by taking averages of a number of undertakings, and his elaboration of details—to establish the superiority of the trackless over every other system of transportation services, are no doubt illuminating. But after all, he has dealt with only one side of the problem.

Public stand-point of view: His exhaustive plea for the railless, for conditions peculiar to the western countries, one can very well appreciate. Any recommedation for its adoption into cities in this country cannot be accepted without some hesitation, unless, in the circumstances of the case it has been proved satisfactorily, that it would provide the most suitable form of transportation, and that it would be economical and acceptable, as well, from a general stand point of the public.

Congestion of traffic: All our provincial cities are faced with congestion of traffic, and the removal of tracks from the streets and the substitution of the trackless system, a plan which Mr.

Stanton seems to favour, would generally increase congestion instead of relieving it.

Tramways: Tram service has proved very convenient for this country, and goes far towards increasing the efficiency with which the available street space is used. The outstanding advantages of the trackless trolley lie in that the capital investment is less, and the working expenses slightly lower: The investigations made by Mr. Station seem to possess little use in the treatment of problems affecting our cities. However, provided our cities were planned on lines like those of Great Britain, his observations could be accepted with little hesitation. Unfortunately, our cities have been peculiarly planned, perhaps it may be said to have been planned without any consideration for the future improvements in mechanical transport, or have been allowed to grow haphazardly and without control.

The trackless trolley has already come to stay in England, America and other countries. The problem has now come to us whether the trackless system may not be introduced to advantage into our cities too.

I would point out that the problem of transportation is one of the most important problems that this country has now to face in a comprehensive manner, and it is really fortunate that Mr. Stanton should have raised the problem of Railless traction for discussion in our Institute.

The Author, in his reply, dealt with the various remarks as follows:—

1. *Col. Sir Gordon Hearn.* It is indisputably true that tramways of an established character are unfairly handicapped by the continuance of an unrestricted competition. The general public of to-day give little or no recognition to the immense part which has been played by the tramway in the development of suburban estate development and since the advent of the motor-bus, are equally indifferent to the necessity for supporting common traffic facilities on lines which designedly utilise each available service to the *best advantage*. The *best* advantage however is provably *not wholly* confined to the utilisation of mechanical advances to the extent which, in Great Britain, has been productive of the cry—scrap the trams. Public beliefs held regarding the benefits which arise from the retention of unlimited competition must eventually react upon themselves and invariably reflect their effects most positively upon the financial aspects of the interests concerned. The solution lies in a proper co-ordination of all city, suburban and urban district passenger transport facilities, to the end that

efficiency may prevail over the *whole*, such a policy should be, conducive to cheap and rapid transport, reduce waste no matter what form it takes and provide for a greater safe-guarding of the capital investment represented than is otherwise possible. The evidence to date is conclusive, that an efficient tramway system cannot be beaten by any other form of existing *open street or road* transport facility, for dealing with the dense traffic conditions to be found in industrial and other massed population areas; nor can any other form operating under similar conditions meet these particular requirements so cheaply and economically. It may be of interest to point out here, that the number of passengers carried *by tramways in Great Britain during the year 1925 was 4,620,501,521* as compared with 1,743,318,314 representing the total number of passengers (inclusive of contract ticket holders) carried by *all* the railways during the same period. Clearly then, any proposals which aim to displace tramways in entirety by any other form of existing transport must give a careful consideration to *all* the conditions which a scrapping of the trams would create.

Adverting to the comments made on Greater London, it is interesting to note, that some of the chief values given under Appendix No. I. London County Council Tramways Year 1923-24 show increases during the year 1925-26, which may be obtained by the use of the following figures :—

London County Council Tramways statistics—1925-26.

Net capital expenditure to 31st March, 1926 ...	£16,381,077
Car miles run	68,804,927
Passengers carried	691,472,969
Average car miles per day per car	128·15
Average car hours per day	14·08
Average fare paid by passenger (pence) ...	1·45

The *continued* utility of the L. C. C. tramway services to the public is well illustrated by the fact that four and a quarter millions of passengers were carried per route mile in 1925-26, compared with three and three-quarter millions per route mile in 1913-14.

Now judged from the advances made since 1925, when the investigation which prompted my paper was carried out, the "railless" system is rapidly leaving the "trying out" period referred to in the comments and noteworthy in a number of additional places where "railless" has been adopted are the cases of Wolverhampton and West Hartlepool. These two Corporations are effecting a complete transition from the tramway service to a new transport service which embodies the *joint* advantages of

the "railless" with the motor bus. At both places, the decisions reached were the outcome of a careful investigation into the relative costs and conditions (local and otherwise), applicable to a consideration of alternatives to the tramway proper and chiefly rendered necessary by heavy expenditures called for under track renewal liabilities. The proved outstanding advantages of the trolley vehicle over the motor-bus were stated to be its acceleration properties, lack of engine noise, vibration and smell. In addition, all the motorbus chassis improvements admit of application to the trolley-bus and overhead equipment provided on the tramway routes is easily adaptable for trolley vehicles without great expense.

2. *Mr. R. D. N. Simham.*—The comments received do not appear to call in any way for either an enlargement or a repetition of the section in the paper which comes under the sub-head "Facilities and Limitations", for that section reviews the respective aspects presented by the tram-car, the petrol motor-bus and the trolley-bus. The paper aims to attract a greater attention to transportation problems which are bound to become of increasing importance to all industrial centres and residential areas throughout India as time goes on. It is not, however, intended to convey the impression that, the adoption of "railless" alone can or will solve those problems of passenger transport in India which are not, nor cannot, be, dealt with by the existing railway systems. The case for "railless" is clearly laid down on Page 54 of the paper and when existing tramways in India either begin to operate with a loss, provably due to calls for expenditure on the relaying of tracks along non-paying routes, or are faced with heavy capital outlays for extensions, then the case for "railless" becomes on a par with the conditions found elsewhere. I fully agree that, treated as a whole, Indian cities have grown up in a hap-hazard style, devoid of system or plan, but there was a time when similar conditions applied to even Great Britain. A similar ruling applies to the development of roads too and as we live in an age when the utilisation of advances made in mechanical traction has forced administrative authorities everywhere to spend money on large scales, that public convenience shall be served, the provision of facilities for cheap and rapid transport has of necessity become a feature of civic and other development works, which no responsible administrative or executive official of to-day should ignore. Adverting to the difficulties presented by narrow streets and the question of congestion, it should not be overlooked, that where in service the trolley-bus forms no greater a factor for congestion than does the motor-bus. Owing to its advantages in acceleration and control it is probably less; on the other hand, it has a

flexibility limitation not applicable to the motor-bus, by reason of the trolley-bus flexibility radius for safe working being limited to a matter of fifteen to sixteen feet for a road width of from thirty to thirty-five feet, which however means, that in the narrow thoroughfares common to most Indian cities and where the conditions admit of overhead trolley wires being erected, a similar flexibility may be claimed for both the trolley and motor-bus vehicles. At West Hartlepool for instance, the trolley vehicle is giving a satisfactory service on streets where (at the most narrow point) the width does not exceed sixteen feet seven inches. Incidentally it may be remarked, that the most recent types of trolley-bus being placed in service carry a deviation indicator for the guidance of the vehicle driver when negotiating traffic. The actual indicator takes the form of a box located in the driver's compartment, which is numbered in feet from the centre to left and right. As the driver manipulates the vehicle in and out of traffic, a light appears in a particular portion of the box showing the extent of such deviation.

3. *Mr. K. R. Godbole.*—Any development of a "railless" system in cities where *no prior conditions* exist, from which data essential to the formation of an estimate of the probable traffic conditions can be ascertained, necessarily calls for a careful study. It moreover calls for the exercise of what (for want of a better term) may be called 'engineering sense' to a greater extent than does the provision say of a fleet of motor-buses, otherwise unremunerative routes containing capital in the form of overhead equipment are sure to result. Poona is a city however, which *inter alia,* possesses an electric supply service anxious to secure outlets for a more or less uniform day-load and the development of new residential areas is also bringing more prominently to the front the needs of local transport facilities; combined, it cannot be doubted that, granted co-operative effort to exist between the local authorities and the electric supply authority concerned, the city of Poona presents possibilities for developing a transportation service advantageous alike to the community served and those with whom the onus of finding the necessary capital may rest. Since the proposals do not call for a consideration of the tramway proper, the investigation of any survey undertaken, will be confined to a study of traffic possibilities, supplemented by a comparison of a motor-bus service as a revenue earning proposition with the trolley-bus. In other comments made, it is observed that an error of interpretation needs correction under (2) where reference is made to the trolley-bus being capable of swerving on the road surface to the extent of thirty-five feet. The proper interpretation to be put on the reference from which the error arose is.

that granted a road surface of thirty-five feet to exist with trolley conductors carried directly in line with the centre, the trolley-bus trolley-boom range of flexibility (as will have been already rendered clear in the reply to Mr. R. D. N. Simham), is such as permits of its easy manipulation at will in and out of any traffic on that road. For streets or roads of greater width, it is necessary to run *four* overhead wires preferably carried on a span construction, which provides for up and down (*i.e.* double track equivalent) service routes. Referring to cost, it may interest Mr. Godbole to know, that a recent estimate for providing a trolley-bus service of ten thirty-two seater pneumatic-tyred vehicles to operate over a conductor route-mileage of ten miles, called for a capital expenditure of Rupees seven lakhs.

4. *Mr. W. A. Buyers.*—The only reply called for here, lies in pointing out, that as related to the concluding paragraph of the comments, the Statistics of Cost in Table I (Tramways) for Ipswich are for *twelve* months, whereas those of Table II (Railless) are from September 2, 1923 to March 31, 1924 only. In the light of additional figures (only obtainable since my paper was sent forward in May 1926), it may serve a useful purpose to draw attention to the following:—

Under Table I. Electric Tramway figures for Ipswich.

Year.	Length of street route miles.	Revenue per car-mile.
1924-25	9.35	16.67 Pence.

Ipswich Railless Service return for the same year—1924-25.

	Length of route open miles—chains.	Revenue per car-mile.
	0.62	15.888 Pence.

5. *Mr. McGlashan.*—Adverting to the remarks made anent Birmingham, since the City of Birmingham presents a useful object lesson in the results obtainable from the labours of a single City Council Committee, who control tramways, trolley-bus and motor bus transport services, it may be of interest to state, that the report for the year ending 31st March, 1926, records a gratifying progress to have taken place in all three forms of transport. Figures are:—

Tramways Service. (*Limited to approx.* 74.5 *miles of facility.*)

Gross Revenue,	£1,470,590,	an increase of	£42,036.
Mileage run,	20,100,363,	an increase of	1,021,750 miles.
Passengers carried,	251,664,435,	an increase of	10,845,978.

Trolley-bus Service. (Limited to 2 miles 40 chains of facility.)

Gross Revenue,	£29,377,	an increase of	£1,532.
Mileage run,	395,862,	an increase of	26,676 miles.
Passengers carried,	5,949,818,	an increase of	402,618.

Motor-bus Service. (Not limited as are the preceding, but restricted in route through co-ordination.)

Gross Revenue,	£230,362,	an increase of	£60,789.
Mileage run,	3,379,211,	an increase of	774,626 miles.
Passengers carried,	29,315,335,	an increase of	8,223,391.

Peculiar as it may appear, the year's results constituted a record from a *tram-car mileage* point of view, more than a million miles in excess of any previous record in the history of the undertaking having taken place. The adequacy of the transport facilities provided *as a whole*, moreover, appears to be reflected by the evidence that the total passengers carried were also in excess of any previous year by nearly 11,000,000.

Regarding the difference referred to in the financial figures shown for Bradford and for Keighley, the differing percentages are the result of conditions controlled by the system of local accountancy and in which the factors taken into consideration are not the same.

Judged from the services examined, instances in which the trolley boom is disconnected through bad or careless driving are few and the drivers rapidly become as expert in controlling the new type of vehicle as they were formerly when driving the tram-car.

The point mentioned regarding the two cars shown as horse-drawn perhaps needs amplification; these two horse cars were in stock at the date of the return, actually, horse traction ceased in May 1915.

6. *Mr. M. R. Atkins.*—I hope the additional information given in previous replies will help to solve the question which relates to Chitpore Road.

Railless vehicles of the latest type are practically noiseless and vibration has been reduced to a negligible degree, which of course does not apply to either the tram-car or the motor-bus.

Anent the remarks made regarding Manicktolla Spur, in the absence of other data the road width stated (54 feet) would appear to lend itself to the adoption of "railless" through a span construction, which (by the use of four conductors) would provide in so far as flexibility is concerned, for up and down routes capable

of moving with ease in traffic within a width of sixteen feet on either side of a centre line taken when the trolley booms rest directly in a line parallel with either of the respective up or down route overhead conductors. This means, that practically thirty-five feet of the entire 54 feet roadway is at the disposal of either an up or down route driver to manipulate in and even in India one could scarcely expect more. Alternatively, if found advantageous, the "railless" could be adopted on its merits as a single track route only, the limitation of flexibility in this case being that of sixteen feet on either side of a centre line taken down the 54 ft. wide road.

7. *Conclusion.*—Although as stated by Mr. Buyers, the field of application for "railless" in India must be limited in application by the very nature of the case, it nevertheless serves to bring aspects of the transport problem before Members of the Institution, which might not otherwise have received attention. In Great Britain the interests of all commercial communities are closely inter-linked with that of local authorities where transport problems are concerned, which may be gathered from the simple growth of the Home Government Road Board Fund; an amount of £2,168,000 paid by Tramway authorities during 1925 in the form of local taxation for the upkeep of that portion of roadways defined as "the tramways permanent way"; and, £3,221,000 paid for 707 million units of electrical energy used for operating same.

In conclusion, I feel it is not out of place to here repeat what I stated in my paper on the subject of railway electrification during 1923—"the advancement of India, as in other countries, is inseparable from the solution of problems of transport, and the attainment of this end will very largely depend upon the amalgamation of interest between the great banking and engineering interests involved, under conditions which will demonstrate that public utilities are in reality a national service." Replies to the discussions raised on the reading have been unavoidably delayed through a desire to make the paper as a whole, when associated with the subject matter of discussions and replies, as informative and complete in its useful data value as possible and I trust all interested in the subject will find that this has been demonstrated to their satisfaction.

8. *Mr. C. V. Krishnaswamy Chetty.*—The mono-rail system is not referred to in the paper because, ***as a commercial proposition for dealing with passenger traffic on lines similar to those covered by the field of the trackless trolley system,*** it does not enter into the problem. To date, practical applications of the mono-rail

system have been extremely limited, the reasons for which may be judged when it is stated that, original *commercial* ideas held regarding the mono-rail system were based upon the production of a means whereby passengers could be conveyed with safety over fairly long non-stop distances at speeds as high as four miles a minute. Apart from all technical aspects, it will be recognised that the securing of facilities for obtaining a right of way across roads, public and private lands, in such a manner as to properly provide for the rail line being built in a perfectly straight line, forms by no means the least of the problems presented in countries similar to England or of even greater density condition.As an example, such a project was at one time put forward as a supplementary or alternative facility to existing steam-operated express railway facilites conveying passengers between Manchester and Liverpool or vice versa (forty miles in forty minutes), by an electrically operated mono-rail service doing the journey in ten minutes.

9. *Mr. R. K. Nariman.*—The question of utilising storage batteries as a means of operating transport facilities is a matter meriting far more attention than it has received. As might be expected, development of this kind stands higher in the United States than it does elsewhere and claims for its expansion usually place stress upon the reduced cost of upkeep when compared to other vehicles, but the price of current for re-charging, the number of vehicles in use and the conditions of use are all factors calling for consideration at a stage where, *in most places,* a lack of *organised charging facilities at low rates exist.* Against their more extensive adoption are the elements of first cost, durability and weight, the latter being particularly disadvantageous. For localities *without an existing tramway,* where it is proposed to seriously consider the development of an *electrically propelled* street or road transport system, the question of whether a storage battery vehicle should be adopted in preference to the trackless trolley, is a matter which *ordinarily*, will admit of solution by reference to the anticipated traffic conditions alone. If however, the problem is one of simply deciding whether to scrap an existing *trolley wire* tramway system for the reasons set forth in the paper, the question of considering whether the proposed new service shall be operated by the trackless trolley as against the storage battery vehicle, will not ordinarily enter into the question, since under present conditions, the advantages of the trackless trolley are too self-evident.

MAIN FEATURES OF THE TANSA COMPLETION WORKS FOR THE WATER SUPPLY OF BOMBAY

BY

S. T. PROKOFIEFF, ASSOCIATE MEMBER.

The Tansa Completion Works Scheme has been the last step in the development of the water supply from Tansa lake, for increasing it from a little over 30 million gallons to 90 million gallons per day, which is estimated to be the draw the catchment can yield in years of normal rainfall.

Consideration of future extension, however, proceeds on the lines of further increase of the Tansa lake capacity for the purpose of storing additional water to be derived from Vaiterna River and provision has been made to admit of laying an additional water main along the present Tansa Completion Works route.

The original Tansa Project was planned in 1872 by Major Tullock. In 1890 Tansa water was brought to Bombay, the conduit having been formed by a masonry aqueduct of about 40 million gallons per day capacity with inverted syphons of 48″ cast iron pipe capable of discharging $17\frac{1}{2}$ million gallons per day.

In 1915 the Tansa Duplication Scheme was completed, consisting of raising the dam and duplicating the inverted syphons between the duct portions by 50″ lock bar steel pipe.

In 1920 the Tansa Completion Works began, the immediate motives for the undertaking being, in brief, as follows :—

(*a*) **Rapid increase in population, as shown in the attached table, and industrial development.**

TABLE SHOWING GROWTH OF BOMBAY WATER SUPPLY.

	1861	1872	1879	1881	1886	1891	1892	1901	1906	1911	1916	1921	1926
	Vehar water introduced 1860.		Tulsi-water introduced		Vehar Supply increased by laying 24" main	Pawai works constructed	Tansa water introduced				Tansa Supply increased		Increased supply from Tansa through 60" Connection between Pawai & Ghatkoper.
Population	7,00,000	6,44,405	7,45,000 Approximate)	7,73,195	8,00,000 (Approximate)	8,21,764	8,30,000 (Approximate)	7,76,006	9,77,822	9,79,445	10,00,000 (Approximate)	11,75,914	12,74,150
Number of Connections	1,061	10,037	12,036	12,817	14,448	17,634	18,113	20,552	20,921	23,314	25,542		31,868
Number of Properties ..	16,902	22,020	23,693	24,034	31,369	33,445	33,557	34,900	36,488	40,864	45,716	48.67	46,138
Supply in millions of gallons per day ..		7	10½	10½	14	14	31½	31½	31½	33½*	46	†40½	63
Supply in gallons per head per day. ..	10	11	14	13½	17½	17	38	40½	32	34	46	34½	49½
Supply in gallons per connection per day. ..	6,920	700	870	820	970	760	1,740	1,530	1,500	1,440	1,800	1,480	1,977
Annual Income from water .. Rs.	45,619	4,07,835	3,51,798	5,24,819	7,74,651	11,81,429	14,07,081	15,47,120	19,38,429	20,89,253	24,71,834	33,31,036	72, 08,00

Note—Increased supply due to enlargement of the northern portion of the Vehar main from " to 48" between the years 199 and 1914

† Restricted supply on account of deficient monsoon.

(b) Serious shortage of water due to failure of 1918 monsoon.

(c) A serious accident to a portion of the old masonry duct in July 1917.

It was also apparent that the water supply available would be inadequate to meet the requirement upon the completion of very large development schemes undertaken by Government, City Improvement Trust, Port Trust and the Municipality.

Plan of the new water mains laid under Tansa Completion Works Scheme and position of Tansa lake are shown on the attached Map (Plate I) among all the other works for the water supply of Bombay.

Beginning at Tansa Dam, two parallel gravity 72″ steel mains are laid upon the formed track till Bassein Creek is reached at Mile 29. The two arms of the creek are crossed by the two specially constructed bridges. The two bridges have also provision for a roadway.

After crossing the creek the two 72″ mains continue till Powai, where, at Mile 40, a site has been chosen for a filter plant and a chlorination plant has been constructed for disinfection of the whole water supply.

South of the chlorination plant the two 72″ mains taper into two 57″ steel mains and a branch leads into a 60″ steel main.

Further, three Venturi meters are appointed on the two 57″ mains and the 60″ main for measuring the whole supply.

The two 57″ mains continue to Bandra where they cross under the B. B. & C. I. Railway Bridge at Mile 47½, and then the mains cross the creek upon a bridge specially constructed. From here the 57″ mains enter the Bombay Island and continue to Nana's Chowk, near Grant Road Station, at Mile 54 1/5, where one of the two mains terminates and is to be connected to two existing inlet pipes into Malabar Hill service reservoir. The second main will continue to Chowpatty Terminal point, at Mile 54½, where cross connections are to be made to three existing outlet pipes from the Malabar Hill reservoir.

The two twin 72″ and 57″ mains are provided with stop valves and cross connected in several places thus dividing the whole length into sections convenient for efficient control of supply, inspection and repairs.

The 60″ steel main is laid upon the formation prepared from Powai towards Ghatkoper, where at Mile 3 it is connected to the two existing Tansa mains of 50″ and 48″ diameter leading into

Bombay island, which mains are branched, eventually reaching both Malabar Hill and Bhandarwada service reservoirs.

Besides the two old Tansa mains already mentioned, the Bombay Municipality are in possession of the following supply mains :—

(1) The Vehar 48″ rivetted steel main leading from Vehar lake to Kurla where it branches into two c. i. 32″ and 24″ Mains, the former extending to Bhandarwada reservoir.

(2) The Tulsi 24″ cast iron main leading from Tulsi lake and eventually reaching the Malabar Hill reservoir.

There is one more small Municipal lake constructed at Powai in 1890, never, however, used, the water not being potable.

While planning the Tansa Completion Works Scheme, consideration was given to the arrangement which would allow of certain interlacing of the new supply mains with the old ones.

On the whole length from Tansa to Mahim and from Powai to Ghatkoper the pipes are laid fully exposed with the exception of the 57″ mains between Andheri Marol and Santa Cruz road crossings where the mains are laid partly or fully in trenches in view of future proposed road over the mains.

The pipes in Bombay island are laid underground.

Hydraulic Calculations.—The new mains have been designed for a discharge of 90 million gallons per day.

Under the advice of an expert, Prof. W. C. Unwin, formula Chezy

$$V = C\sqrt{R\,S}$$

was used, the value of C being taken as 108; the professor based this choice on the observations by Hershel and Marx for rivetted steel pipes of large diameters.

For discharge of 90 million gallons per day (167 cusecs) by two 72″ mains according to the formula

$$Q = 2 \times \frac{\pi d^2}{4} \times 108 \sqrt{\frac{d}{4} \times S}$$

the hydraulic gradient equals

$$S = \cdot 00048.$$

Loss of head on the length from Tansa to Powai will equal

$$\cdot 00048 \times 215100 = 103\cdot 28 \text{ feet.}$$

Head of water at Powai, when water is drawn at an average level of Tansa lake (400·00 T. H. D.) will equal

$$400 - 103\cdot 28 = 296\cdot 72 \text{ T. H. D.}$$

For an average head of water at Malabar Hill reservoir of 247·00 T. H. D., the available head along the 57″ line is

$$296\cdot 72 - 247\cdot 00 = 49\cdot 72 \text{ feet;}$$

thus, the hydraulic gradient will be

$$\frac{49\cdot 72}{73800} = \cdot 000674$$

According to the same formula the two 57″ mains will discharge

$$q = 2 \times \frac{\pi d^2}{4} \times 108 \sqrt{\frac{d}{4}} \times \sqrt{\cdot 000674}$$

$$= 108\cdot 5 \text{ cusecs} = 58\tfrac{1}{2} \text{ million gallons per day.}$$

The remaining

$$90 - 58\tfrac{1}{2} = 31\tfrac{1}{2} \text{ million gallons per day}$$

= 58·5 cusecs will be discharged by the 60″ main, the hydraulic gradient working out at

$$\cdot 000614,$$

from the same formula.

The loss of head along the 60″ main will equal

$$16500 \times \cdot 000614 = 10\cdot 13 \text{ feet}$$

and the head of water at Ghatkoper

$$290\cdot 72 - 10\cdot 13 = 286\cdot 60 \text{ T. H. D.}$$

Formation level at Ghatkoper being

$$171\cdot 27 \text{ T. H. D.,}$$

the pressure in the two 50″ and 48″ old Tansa pipes will at Ghatkoper equal

$$\frac{286\cdot 60 - 171\cdot 27}{2\cdot 31} = 50 \text{ lbs. per sq. inch.}$$

The maximum pressure in the pipes discharging as above will be found at Mile 28 equal to $\frac{238}{2.13} = 103$ lbs. per sq. inch.

The maximum static pressure (in Bombay, at Haines Road crossing) would equal

$$420 - 68{\cdot}00 = 352 \text{ feet} = 152 \text{ lbs per sq. inch.}$$

The hydraulic gradient as per above calculations is shown on the Longitudinal Section (Plate 2).

It will be observed that the formation is just below the hydraulic gradient upon the hills at Miles 4-6 and 38 39.

The main parts of the Tansa Completion Works Scheme have been as follows:—

(1) The raising of Tansa Dam and building a new outlet well.

(2) Construction of the pipe track from Tansa to Bandra and from Powai to Ghatkoper.

(3) Manufacturing of about 81 miles of 72″ diameter steel pipes; of about 28 miles of 57″ steel pipes and about 3 miles of 60″ steel pipes.

(4) Transporting and laying of 72″ and 57″ twin mains upon the formation from Tansa to Bandra and a 60″ single main from Powai to Ghatkoper.

(5) Transporting and laying in trenches two 57″ twin mains within the island of Bombay.

(6) Erection of sluice valves, cross connections; air and scour valves; expansion joints and other appurtenances and construction of anchor blocks, etc.

(7) Construction of a chlorination plant for disinfection of the supply, at Powai.

(8) Increasing the storage capacity of the service reservoirs in Bombay.

(9) Pitometer survey of all the trunk mains in Bombay and investigations for remodelling the distribution system.

(1) *Raising of the Tansa Dam.*—The maximum section of the Tansa Dam, as originally designed is shown on Plate 3. When first constructed in 1890 the crest level was brought up to R.L. 410 T.H.D. The dam was raised subsequently in 1915 to the R.L. 419·58 T.H.D.

Under the Tansa Completion Scheme the crest level has again been raised to R.L. 423 T.H.D. (with spill-way at R.L. 420) *i.e.* two

feet below the limit of height to which the dam had been designed; the material of the dam being rubble masonry in natural hydraulic lime mortar, similar to the original construction.

A new outlet well has now been constructed to accommodate the outlet pipes and screening gear.

By raising the dam the lake capacity has been brought to about 35,000 million gallons.

The Tansa catchment area is 53 sq. miles.

The average run-off from the catchment is calculated to have been 57·6″ per year, which amounts to an average yearly discharge of 41,160 million gallons from the catchment area.

The average yearly rainfall at Tansa dam is 91 inches (maximum 133 inches, minimum 40 inches).

(2) *Construction of the Pipe Track.*—The pipe track has been prepared of the following width at the formation level:—

(*a*) 27 feet for the twin 72″ mains.

(*b*) 18 feet for the single 60″ mains.

(*c*) 25 feet for the twin 57″ mains, which has been narrowed down to 20 feet across the Bandra creek (where no permanent tram line is laid).

Railway track 2′ 6″ gauge of 25 lbs. rails upon steel sleepers, at 3′ centres, has been laid alongside for transporting earth, materials, pipes, etc., and for inspection purposes.

The width of the pipe track has been made sufficient for placing the rails for a goliath crane to span over the tramway line and the pipes.

The length of the pipe track from Tansa to Mahim is 48 miles and the length of Ghatkoper branch 3 miles.

About 85 million cubic feet of earth work has been done in excavation and embankments by the contractors, the Tata Construction Co.

The attached photographs show:—

(1) A cutting through rock, and

(2) An embankment prepared for pipe laying about 40′ high.

Most of the cuttings through bazalt rock were worked by blasting with hand drilling, though in some cases pneumatic drills were used with advantage.

Generally, all the curves have been laid out to standard railway curves of 1, 2, 3, etc. degrees for the pipes to be laid in chords with bevelled bend plates of the three standard sizes for 1°, 3° and 5° deflections, the chords being made in suitable lengths to conform to the curvature of the track so as not to foul either the tram line or the goliath crane track.

The maximum grade of the track allowed has been 1 in 40.

The minimum radius of curves has been 250 feet.

Numerous culverts and several bridges were built to carry pipes over creeks, rivers, nullahs, etc. The maximum opening spanned over by pipes has been 30 feet (for 57″ mains), the length being justified by the following calculations for 57″ steel pipes 3/8″ thick.

Tensile stress due to interval pressure of 150 $\frac{\text{lbs.}}{\text{sq. inch.}}$ according to Balrow's formula

$$f = \frac{p\,D}{2\,t}$$

is equal f = 11400 lbs per sq. inch,

Safe stress = 15000 lbs per sq. inch.

15000 - 11400 = 3600 lbs per sq. inch represents margin for additional stress in bending.*

Maximum stress due to bending

$$f_{,} = \frac{My}{I}$$

$$\text{Where} \quad M = P\frac{X^2}{10}$$

$$\text{Hence } f_{,} = \frac{X^2}{10}\cdot\frac{y}{I}$$

$$\text{and} \quad X^2 = \frac{10\,I\,f}{P\,y},$$

P = weight of pipe (with water) = 1240 $\frac{\text{lbs.}}{\text{per foot.}}$

= 103·3 lbs per inch.

Y = 29·25 inch

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* Arithmetical sum of stresses is considered in place of geometrical.

I net = I gross − I rivet holes.

$$I = \pi \frac{(D^4 - d^4)}{64} = 27820 \text{ (inch)}^4$$

Number of rivet holes ($\frac{3}{4}'' \times \frac{3}{8}''$) = 82

I of rivet holes = $2 \times (18 \cdot 59)^2 \times 11 \cdot 53 = 7945$ (inch)^4

I net = 19875 (inch)^4

$X^2 = 236800$; X = 487 inch = 40 feet, approx.

As regards rivet shearing, the stress due to internal pressure

$$e = \frac{P}{n \times \frac{\pi d^2}{4}}$$

Where P = 150 × 2551 = 382755 lbs,

n = 82; d = $\frac{3}{4}''$

e = 10600 lbs. per sq. inch.

Safe stress = 12000 lbs per sq. inch

12000 − 10600 = 1400 lbs per sq. inch is a margin for additional stresses.

Bridging over south arm of Bassein creek presented a considerable problem in itself, which it is not the intention of the author to discuss. The steel bridge constructed by Braithwaite and Co., Engineers Ltd., consist of 13 spans 138′6″ between centres of the piers.

The north Bassein bridge consists of 10 spans of 44′ between centres of piers.

Both the Bassein creek bridges have provision for laying additional 72″ main. The pipes are supported by c. i. saddles placed at about 14′4″ centres.

The Bandra Creek bridge consists of 6 spans of 34′ between centres of piers; the pipes are supported on reinforced concrete saddles.

Concrete piers on both Bassein North and Bandra bridges have been done departmentally and the steel work by Braithwaite and Co., while remaining bridges and culverts by the Tata Construction Co.

(3) *Manufacturing of the Steel Pipes.*

Design.—(Plate No. 4). All the three sizes (72″, 60″ and 57″) of the pipes used on the work are made of mild steel plates 3/8″ thick with lap joints, single line of rivets for circumferential joint and double rivetted longitudinal joint. Each plate for straight pipes is 7′2″ long between rivet holes. The pipe strakes are alternatively inners and outers, the inside diameter of the inner strakes indicating the size of the pipes; 3/4″ rivets have been used throughout with $2\frac{1}{4}$″ pitch, approximately, and $1\frac{1}{8}$″ minimum distance from the edge.

All plate edges are bevelled to an angle of 70°, suitable for caulking. Corners of the plates are machine scarfed for a distance of $2\frac{1}{2}$″ from edge for entering the pipes at the joints.

Specials—For curved portions bevelled plates have been used of standardized sizes for 1, 3 and 5 degrees deviation, about 2′ long on the centre line of the tube formed, giving minimum radius of about 21′ (for 5° bend).

Expansion joints have been formed with 3′6″ overlap as shown on the drawing.

Taper reducing pieces have been formed with two horizontal double rivetted butt joints.

Branches for air and scour valves and for cross connections have been made of the two halves joined by rivetted butt straps and the joints have been welded by acetylene flame.

The complete manufacture of plates including drilling of rivet holes and scarfing of edges was carried out in the Redcar Works of Messrs. Dorman Long and Co., near Middlesborough, and the plates were shipped flat to Bombay, which effected a net saving estimated at Rs. 30 lakhs, as the ocean freight has been reduced to one-fifth of that of shipping tubes.

Manufacturing of the pipes from the plates has been done in the Mulund factory of Messrs. Braithwaite and Co. The factory is situated near Mulund Station of G. I. P. Railway and connected with the main line by a broad gauge siding.

The workshop consists of five bays 75 feet span each. The railway siding runs through the central covered bay, which has been served by four 6 tons electrically operated magnet cranes used for lifting the flat plates from the railway tracks and stacking them on both sides of the track. On both the sides of the railway

track within the two also covered bays are placed four electrically driven plate rolls, each operated by a 50 B. H. P. motor.

These rolls were specially designed for the job; the upper roll can be lifted or lowered by power and adjusted to very close limits to ensure correct curvature.

The edges of the rolled plates were bolted together and the cylinders formed taken by overhead cranes for rivetting which was done on hydraulic rivetters with an 8′6″ gap, exerting a pressure of 60 tons on a rivet. During rivetting the pipes were supported on turning cradles, hand operated, travelling on rail tracks.

The pipes were assembled, generally, in eight strakes of 57′4″ long. As pipes left the rivetters they were mounted upon the rotating stallages within the two outside unroofed bays for caulking (inside and outside), all the caulking having been done by pneumatic hammers working at 95 lbs. pressure.

After caulking the pipes were painted with bitumastic paint (Bowranite). It would be of interest to mention that painting with pneumatic sprayers was found affecting workmen's eyes and lungs very seriously and was substituted by hand painting.

The caulking bays were provided with two overhead cranes of 10 ton each for handling the pipes after painting, turning them and loading on the bogies which run upon 2′ 6″ rail track laid on the outside. From here the pipes were marshalled into trains usually of 8 pipes 57′4″ each ready for transport to the field by steam locos.

The power for the factory has been provided by three high speed Bellis and Morcom Engines direct coupled to d.c. generators, the total output being 800 H.-P. All the machinery of the factory was driven electrically. Two air compressors each of 550 cubic feet of air per minute capacity supplied air into a receiver from which air was distributed in the workshop by a ring main. Three pumps delivered together 130 gallons of water per minute under 1,500 lbs. per sq. inch into a hydraulic ring main.

(4) *Transporting and laying of the steel mains from Tansa to Mahim and on Powai-Ghatkoper Branch.*

The trains of pipes were carried along the 2′6″ railway already prepared upon the pipe track to the erecting stations. As the pipes were sent to the field in 8 strakes lengths, only one annular joint out of eight was rivetted in the field.

Travelling on rails goliath derricks spanning over the pipe track and railway line were equipped with 20 tons travelling cranes, all

movements hand operated. The cranes unloaded the pipes from the trains at the erecting stations, traversed them into position and suspended the pipes for assembling.

The easiest way for joining a pipe to one already laid was found to be by placing the outer strake of the pipe—suspended by chain slung near the centre of the pipe—over the inner; then by lowering until the top hole of the outer matched the top hole of the inner. The free end of the suspended pipe was held a little higher and the topmost rivet hole was engaged with a pointed bar passing through the topmost rivet hole of the pipe already laid. The free end of the pipe was then slowly lowered, the weight of the pipe forcing it over the inner strake of the pipe laid.

Rivetting and caulking were done by pneumatic tools. Portable air compressors of 180 cubic feet of air per minute capacity were steam driven at the beginning; a complete outfit was mounted on a steel platform placed on top of the pipes already laid; the outfit was moved by the goliath crane, as work proceeded.

This arrangement was, however, found unsatisfactory as the weight of the sets caused the pipes to oscillate considerably; the sets were cumbersome (weight about 12 tons) and much time had to be occupied for moving them forward. These sets have therefore been replaced by the compressors of similar capacity direct coupled to semi-diesel engines or by the sets kerosene oil driven, the whole outfit being mounted on a carriage to run on 2′ 6″ tram line.

The rivets were inserted from inside and kept by a holder supported across inside the pipe, while rivet driving was done from outside.

The joints were caulked both from inside and outside.

Field joints were then examined by municipal inspectors. Hydraulic test was done to a completed section of pipes and all visible leaks have then been made tight. No allowable leakage was specified.

Field joints were then painted over as well as the top portion of the pipes outside, which had been left unpainted in the shop for weather to remove mill scale from the plates.

Rate of progress.—The double line of 72″ pipes, 41 miles long, i.e., 82 miles of piping have been manufactured and laid in 16 working months, an average of over 5 miles per month.

Maximum monthly progress of laying and rivetting in the field of 72″ pipes was 11 miles. Maximum length fabricated at Mulund and transported was 6 miles of 72″ pipes in one month.

(4) *Work in Bombay Island. Trenching, transporting and laying of the steel pipes in Bombay Island.*

Design.—Detailed survey and enquiries were made as to the position and dimensions of the underground services existing and proposed along the Tansa route. The top of the new steel mains was generally appointed 6 feet below the road surface to provide sufficient room for passage of house connections to drains. At roads and underground services crossings the Tansa Mains were carried deeper, underneath the services (maximum depth reached was 20 feet), using standard bend plates, chiefly 5°, for drooping and rising curves.

In crossing over a large double barrel concrete drain the 57″ mains were left exposed, having an expansion joint in the middle as shown on the drawing (Plate 5).

Unbalanced pressure $P_1 = 2\ P \sin \frac{a}{2}$, where

$$a = 15^\circ$$

P (internal pressure) $= 150 \times 2551 = 382755$ lbs.

$P_1 = 99400$ lbs.

$$R = P_1 \times \cos 7^\circ\ 30' = 98400 \text{ lbs.}$$

Weight of pipe with water $1240 \times 39{\cdot}5 = 48950$ lbs.

Moment $M = 99400 \times 11 \quad 48950 \times 19{\cdot}75 = 405{\cdot}000$ lbs. ft.

Additional stress due to M

$$f = \frac{My}{I} = 7040 \frac{\text{lbs.}}{\text{sq. inch.}}$$

Tension due to internal pressure of $150 \frac{\text{lbs.}}{\text{sq. inch.}}$

$$\frac{p\ D}{2\ t} = 11400 \text{ lbs per sq. inch.}$$

Shearing stress on rivets due to internal pressure

$$\frac{382755}{82 \times \frac{\pi\ (\frac{3}{4})^2}{4}} = 10600 \frac{\text{lbs.}}{\text{sq. inch.}}$$

The total tensile stress

$$11400 + 7040 = 18500 \frac{\text{lbs.}}{\text{sq. inch.}}$$

Total shearing stress on rivets is found to exceed

$$12000 \frac{\text{lbs.}}{\text{sq. inch.}}$$

Therefore, to counteract the unbalanced pressure, the pipes have been anchored to the body of the concrete drain underneath. A photograph illustrates the work at this crossing.

Horizontal curves followed naturally the curvature of road and were formed generally as already described under "The construction of the pipe track"; several sharp curves were made entirely of bend plates, without intervening chords, the minimum radius being 21' for curves made of 5 degrees deviation bends; the biggest deflection reached 88°.

No provision for additional protection of pipes laid under ground against corrosion or for additional strength were generally made. But concrete jacketting was resorted to at the crossings of underground services or open drains. After some experimenting a section of concrete was adopted as shown on the drawing (Plate 5).

The pipes were transported to Bombay island in trains along the 2' 6" railway line as far into the town as was found possible for the line to be laid and locos to be used. The pipes brought were made chiefly in 6 strakes, *i.e.*, 13' long and often in 4' strakes and even 2' strakes. At the terminus of the tram line a large space was provided for stacking the pipes. From this point the pipes were transported further on trailers by 2 ton Fordson tractors.

Unloading of pipes from the rail tracks and loading upon the trailers in the store-yard was done by rolling upon inclined pieces of timber. Where the railway line was laid alongside the trench the pipes were unloaded from the train by a goliath crane and lowered into the trench. Some of the pipes were rolled into the trenches from the sloped side, controlling the movement by a rope.

The trenches were made 14 feet wide, giving 9" clearance on both sides, sufficient for timber shoring. Where the concrete jacketting was appointed the trenches were cut 15 feet wide and more when necessary. The section adopted for trenches exceeding 15 feet in depth is shown on Plate 5.

Estimated quantity of surplus earth was removed from the top portion of the trenches by tipping wagons along the tram line or by motor lorries where no tram line was laid.

The sides of the trenches were sheeted whenever necessary, the sizes of timber as per general instructions for shoring being:

(a) Vertical planks 2" or 3" driven 2' into the ground.

(b) Waling plates 8" × 6".

(c) Struts 8" × 6".

For driving the planks a 1 cwt. wooden hammer was used sliding upon an iron bar fixed to a cap placed over the top of the plank, the hammer being lifted either by hand or by a rope passed through a pulley fixed to the crane overhead.

For concreting around the pipes the instructions were to prepare 2′ wide concrete walls at, usually, two strakes distances, previous to lowering the pipes and to complete the concreting around after the pipes were assembled, rivetted and caulked. Circumstances excluded the possibility of charging the pipes with water under pressure before concreting around, to ensure a regular cylindrical shape of the pipes.

Assembling of the pipes was done with the help of derrick cranes of 18 to 25 feet span, on wheels, hand-operated and equipped with 5 or 10 tons chain blocks--in very much the same way as described under laying of pipes outside Bombay.

The rivetting and caulking equipment consisted of portable gasoline driven Ingersoll Rand's air compressors of 90 and 150 c. ft. of air per minute capacity, delivering air at 100 lbs. pressure, with armoured air distributing hoses.

De-watering of Trenches.--Both during excavation and pipe laying pumping out of water was necessary when the trenches extended below subsoil water level or in cases of trenches flooded by rain water or from damaged water mains and sewer drains. Several types of small pumps were used by the contractors, in some cases use was made of the Fordson's tractor engine. In other cases a powerful municipal 6″ centrifugal pump was used and once a fire engine was called upon for quick *de-watering* of a deep trench.

Trench Refilling.--As already mentioned circumstances precluded charging the newly laid mains with water. Therefore no hydraulic test could have been made. After examination of pipes by municipal inspector and painting over the joints the refilling began, the instructions demanding plentiful watering and ramming of the refill. In consequence of a careless refilling the pipes oscillated to the extent of over $2\frac{1}{2}''$ distortion of the horizontal diameter, as was found in the inspection pits.

Observations were made on the effect of passing a 15-ton road roller over the trenches with 6 feet earth filling over the pipes, after a thorough consolidation; no perceptible deformation was observed, the earth load being $4{\cdot}17 \dfrac{\text{lbs.}}{\text{sq. inch}}$ and the load from the roller only

$0{\cdot}43 \dfrac{\text{lbs.}}{\text{sq. inch}}$ (assuming transmission of load through earth filling at 45°), *i.e.*, only 10 per cent of the former. The total load $= 4{\cdot}17 + 0{\cdot}43 = 4{\cdot}60 \dfrac{\text{lbs.}}{\text{sq. inch}}$. According to Love's formula collapsible load for thin steel tubes

$$P = 45346800 \left(\frac{t}{D}\right)^3 \frac{\text{lbs.}}{\text{sq. inch}}.$$

$$\text{In our case } P = 13{\cdot}03 \frac{\text{lbs.}}{\text{sq. inch}} \text{ and safe}$$

$$\text{load } \frac{P}{3} = 4{\cdot}31 \frac{\text{lbs.}}{\text{sq. inch}}$$

Special Works.—Numerous underground and surface services required either supporting or divertion or modification, as well as roads affected required divertion and maintenance ; passages were to be provided over the trenches for foot and vehicular traffic, etc. Two large open drains were crossed underneath. In case of one the flow was carried over the Tansa trench through a 57″ pipe laid upon the bottom of the drain. In another case the flow was temporarily diverted. Large c. i. water pipes had to be supported by masonry pillars. Several storm water drains were syphoned underneath the Tansa Mains. High tension electric cables were slung by ropes or wires to heavy section rails or even to a cable stretched over the trench and anchored on its sides.

Rate of progress, dependant on the conditions, was from 500 feet of double pipe line laid in a week in trenches without shoring to 85 feet and even considerably less in deep trenches heavily shored and with plenty of water to be pumped out.

The work was suspended for the monsoon. The empty pipes laid had to be loaded over to prevent their floating. On one occasion the pipes floated due to heavy rain which flooded the site to the extent of fully submerging the pipes, the earth cover having being made from 2″ to 1′ 6″.

The upward pressure of water acting upon fully submerged 57″ pipe being (for foot run)

16 (area) × 62·4 − 250 (weight of Pipe) = 750 lbs.

the depth of earth cover sufficient to withstand the upward pressure, assuming 3ft. as the width between the lines of rupture, would be

$$X = \frac{750}{3 \times 100} = 2\tfrac{1}{2} \text{ feet, approx.}$$

(6) *Erection of sluice valves, cross connections, air and scour valves, expansion joints and other appurtenances and construction of anchor blocks, etc.*

Head regulating valves of 48″ diameter are installed outside the outlet well at Tansa lake. These valves are hydraulically operated. The remaining stop valves on the whole line are of 36 ins., those which are likely to be often used are provided with hydraulic cylinders. The valves are connected to the mains by taper reducing pieces of 20° taper on the upstream side and 5° on the downstream. The size of valves adopted for cross connections is 24 ins. diameter. Scour valves mostly of 12 ins. diameter are provided for draining the water out of the mains. The sluice valves on the inlet and outlet pipes at Malabar Hill reservoir (in use four times a day) were provided with individual electric motors with automatic cut off switches.

Automatic air valves of double types, mostly of 8″ ins. diameter are fixed at the summits over stop valves of the same size.

Manholes of 14 ins. diameter are provided along the mains for the purpose of inspection and repairs. All "dipps" in Bombay are provided with manholes for possibility of pumping out water from the mains where there are no drains available at a lower elevation.

All the valves and manholes placed underground are provided with chambers suitable for handling the valves and inspection.

Expansion joints at every 1,000 feet have been inserted in the pipes laid exposed to relieve the metal from temperature stresses, as shown on the drawing (Plate 4). For the temperature varying in the year from 50° to 140° F. and the coefficient of linear expansion ·000007 per degree Fahrenheit, the elongation for 1,000 feet of pipe will reach

$a \; tl = \cdot000007 \times 90 \times 1000 \times 12 = 7\frac{1}{2}$ ins.

The lap provided is 3 ft. 6 ins.

The temperature stress will reach

$$S = \cdot000007 \; Et,$$

where E, modulus of elasticity $= 30{,}000{,}000 \dfrac{\text{lbs.}}{\text{Sq. inch}}$.

$$S = \cdot000007 \times 30000000 \times 90 = 18900 \; \frac{\text{lbs.}}{\text{Sq. inch}}$$

exceeding the safe stress assumed at $15000 \dfrac{\text{lbs.}}{\text{Sq. inch}}$

In the underground pipe line in Bombay the expansion joints were used with advantage for joining at the meeting points of pipes laid by two stations to fill up the odd length of a gap, no matter if the lines of longitudinal rivet holes did not coincide.

To free the stop valves on the line from the stresses set by temperature in the pipes, expansion joints have been fixed on both sides of the valves beyond the reducing taper pieces; this also relieved the c.i. cross connection pipes and valves from being strained on account of temperature movement in the steel mains. Packing the glands of the expansion joints with hemp or jute fibre or with lead wool was found unsatisfactory and the joints have been made by first caulking into the gland a ring of ½ in. lead piping, then yarn packing and again another ring of lead piping.

The expansion joints are found leaking perceptibly and after repeated tightening of the gland the angle rings get bent, which indicates weakness of the angle section.

For fixing the stop valves rigidly in their position heavy *reinforced concrete anchorages* have been constructed. Two pairs of angle iron rings are rivetted on the strake next to the tapers and holes drilled in the rings to receive the reinforcing bars.

The whole structure is through-shaped of 53 ft. long (for the twin 72 ins. main), and 20 ft. wide filled with heavy stone filling to provide sufficient weight to resist sliding under maximum thrust which equals

$$2 \times \frac{\pi d^2}{4} \times 150 \frac{\text{lbs.}}{\text{sq. inch}} = 2 \times 270 = 540 \text{ tons.}$$

Assuming coefficient of friction at 0.5, the necessary weight would be

$540^t \div 0{\cdot}5 = 1{,}080$ tons.

Overturning moment

$540^t \times 8 = 4{,}320$ ton-feet, while resisting moment $1{,}080 \times 27{\cdot}6 = 21{,}350$ ton-feet.

The front walls have double reinforcement of double line of bars at each angle iron ring and were considered in the calculations as cantilevers resisting a bending moment equal.

$540 \times 3 = 1{,}620$ ton-feet

The bottom plate is made safe to resist compression and bending. The side walls are calculated to withstand the thrust of the filling inside.

The twin 57 ins. mains are passing underneath the Railway bridge at Bandra Creek upon a rubble bank affected by tidal waters to the extent of partial submerging the pipes by 2·80 feet from the formation, at high tide.

The pipes have been anchored down by iron straps of 3 ins × 1 in. section, fixed in the reinforced concrete blocks constructed at 4 strakes intervals.

With area of water displaced at high tide equal 10 sq. feet for each pipe and the weight of 1 foot of empty pipe equal about 250 lbs., the upwards pressure equals

624 – 250 = 374 lbs per foot run.

The weight of the blocks (in water) is to withstand the upward pressure exerted upon the pipes.

The importance of air valves providing the passage for the air, was accentuated on one occasion when an isolated section of 72 ins. main was being emptied. An 8 ins. air valve had been shut off by workmen and vacuum formed in the main resulting in the *pipe collapsing.*

The angle ring of the nearest expansion joint bent less than the inner strake thus forming a passage for the air and preventing the collapse from further extension.

No rupture of the steel plates or rivet shearing or distortion were caused. The 6 ft. pipe was flattened to an average height of 37½ ins., the height of only 6½ ins. having been observed near the air valve.

After jacking the collapsed expansion joint and admitting water into the pipe under pressure, the pipe assumed under 40 lbs. per sq. inch circular shape, though not altogether to the extent of a perfect cylinder.

(7) *Construction of Chlorination Plant for disinfection of the Tansa Water Supply.*

The Tansa water, though generally of very good quality, becomes turbid during the monsoon and is found to contain disease-forming bacteria of which b.coli contents is accepted as indicating a degree of contamination. The bacterial contents as found in raw Tansa water by analyses in Municipal laboratory averages in minimum number of 0·1 c.c. containing b. coli (Houston's), while strict specifications insist on total absence.

In view of turbidity disinfection alone cannot be considered as absolutely rendering water safe. The experts whose advice was obtained opined in desirability of filtration of Tansa water.

The filter installation is however postponed. In the meantime gravity rapid sand filters on the Paterson system are being constructed and experimented with for treatment of water from other Municipal lakes.

To safeguard the purity of Tansa water at present, in addition to protecting the Tansa catchment area, a chlorination plant at Powai has been constructed by Paterson Engineering Co. capable of treating the whole supply of 90 million gallons per day with liquid chlorine for varied dosages up to about 1.4 part per million parts of water, according to "chlorine demand" of water to be ascertained by residual chlorine tests. The plant is arranged for independent chlorine supply and control for each of the two water mains. Two pairs of Paterson's Manometer type chloronomes with maximum capacity of 25 lbs. of chlorine per hour have been installed. Eight weighing machines of 12 cwt. capacity each are provided for checking the weight of chlorine consumed. Chlorine is led from the chloronomes through acid seals to the absorption towers to be dissolved by water and the solution enters the underground tanks (two) from which the solution is pumped into the mains.

The site of the plant chosen for convenient management has elevation of 165 T.H.D., about 130 feet below the hydraulic gradient, and 255 feet below maximum Tansa static pressure. 3 ins. Durion, chlorine resisting pumps are provided capable each of 3,000 gallons per hour delivery against maximum head of 220 feet through chlorine resisting alcumite piping and valves into the mains, the solution being discharged through nozzles of the diffusers into 24 ins. diameter enamelled iron tubes about 50 feet long fixed inside the mains to prevent chlorine attacking the steel mains and fitted with baffles to promote thorough mixing.

Two Cole's recording pitometers with maximum capacity of 2.3 million gallons per hour each are installed to indicate the changeable rates of flow in the mains. The power for the whole plant is provided by one of the two installed Petter's crude oil 18/21 B.H.P. engines.

(8) *Increasing the Storage Capacity of the Service Reservoirs in Bombay.*

The north part of the Bombay Island is supplied by water directly from the supply mains, which mains extend further south

and terminate at the two reservoirs: (1) Malabar Hill Reservoir and (2) Bhandarwada-Reservoir; from which the south part of the Island derives its supply. Thus, the two reservoirs could be termed both balancing and storage reservoirs.

At the outset of the Tansa Completion Works the supply was intermittent, being available for certain number of hours in the morning and in the evening during the time of maximum demand. For fire extinguishing purposes the reservoirs were never allowed to be entirely emptied.

Till the year 1922 the storage capacities were:

(1) Malabar Hill Reservoir—24 million gallons;

and (2) Bhandarwada Reservoir—11½ million gallons.

Total 35½ million gallons.

As the total daily supply determinated by the Pitometer Survey was at the time about 44 million gallons, the available storage represented

$$\frac{35 \cdot 5 \times 100}{44} = 80\tfrac{1}{2}\% \text{ of the daily supply.}$$

With the increased supply of 90 million gallons per day the storage available would equal a little over ⅓ of the supply.

To increase the inadequate storage accommodation the reservoirs have been enlarged to hold:

(1) Malabar Hill—29¼ million gallons.

(2) Bhandarwada—20¾ million gallons.

Total 50 million gallons.

A third reservoir of 6 million gallons capacity has been designed at Sion Hill and proposals made for a large storage reservoir of about 230 million gallons capacity at Ghatkoper.

The work of increasing the storage of Malabar Hill and Bhandarwada reservoirs had followed one another and the constructional features were somewhat similar. The concrete covering comprises concrete vaulting of about 10 feet span, 4″ at crown and 5″ at skew-backs, supported on concrete spandril walls, 8″ thick resting upon 15″ × 16″ concrete arches of about 20 feet span, supported on concrete pillars. At Bhandarwada, large number of bricks from the old filters being available, some of the supporting

arches of 18 feet span are of brick 18″×18″. Vaulting over larger (20 feet) spans at Bhandarwada is of reinforced concrete 6″ at crown and 9″ at skew-backs, the thickness of spandril walls and section of supporting arches are suitably increased.

Cracks across the concrete vaulting at Malabar Hill have formed. Therefore the construction at Bhandarwada has been improved upon by providing expansion joints every 10 feet, filled with asphalt of suitable degree of penetration.

Haunches of the vaulting have been sloped and drains provided therein. The roofing has been covered with earth and public gardens laid upon the reservoirs.

(9) *Pitometer Survey of the Trunk Mains in Bombay and Investigations for Remodelling of the Distribution System.*

The Pitometer Survey extended over six months and embraced all supply and distributing mains over 12″ diameter up to 48″, number of stations being 64.

The Pitometers in course of the survey were tested against Venturi meter's readings and the results are shown in the following table:

Water Main		Rate of flow in gallons per hour.		Difference in %	Velocity of water; feet per second.
		By Ventury	By Pitometer		
1.	Vehar 24″	192000	194000	1%	2.82
2.	Vehar 32″	246500	249200	1.1%	2.00
3.	Tansa 48″ New ..	793000	792000	−0.13%	2.81
4.	Tulsi 24″ . ..	177000	180750	2.1%	2.62

Note.—The Venturi meters readings have been taken from diagrams; the Pitometer results were calculated from the deflections of liquid in a U-tube by formula

$$V = C\sqrt{2g\,D(x-1)}.$$

The above results speak well for the Pitometer. It will be observed that the velocities were between 2 & 3 feet per second. There was no opportunity to test the accuracy with lower velocities.

The Pitometer recording instruments gave accurate results, as compared with calculations based on manometer readings, for velocities over 1.5 feet per second. Below that value, the recorders showed errors on the slow side, reaching in one case 70% of error for a velocity of 0.5 feet per second.

The Pitometer survey gave to the Bombay Water Department necessary information, lacking before, for drawing up a balance sheet of water supplied, distributed and consumed, as shown in the table.

Water consumption per capita was found equal to 37·3 gallons. The *domestic* average daily consumption per capita equalled 28·7 gallons.

The domestic consumption in different wards was found as follows:—

Ward.	Domestic consumption per head, per day.
A	54·9 gallons.
B, C, D, E, F together	29·3 gallons.
G	14·4 gallons.

The striking difference in consumption of water between A and G wards depends to a certain extent on the standard of living and on the presence of large transient population in A ward coming there for daily work. But it should partly be explained by waste of water in consequence of the supply being intermittent in A ward, while the supply in G ward was constant.

BALANCE SHEET OF WATER SUPPLIED, DISTRIBUTED AND CONSUMED IN 1922 IN MILLION GALLONS PER DAY.

	Outside Bombay Island.	Municipal Wards A	B	C	D	E	F	G	Malabar Hill Reservoir.	Bhandarwada Reservoir.	Total Venturi Meters.
Tulsi 24" Main	0.16							3.94			4.10
Vehar 24" Main .. .	1.03						2.85	0.32			4.20
Vehar 32"						1.38	0.62			4.00	6.00
Tansa 48" New					1.72 / 2.05	1.63 / 1.55	0.40 leakage		11.40	0.50	19.25
Tansa 48" Old . ..					1.37	1.41	3.62	0.90	1.70	2.50	11.50
From Malabar Hill Reservoir ..		6.00		4.94 / 2.16					13.19		
From Bhandarwada Reservoir .			B & E 6.15			0.85			7.00	Total outlets from the two reservoirs. 20.10	
Total ..	1.19	6.00	B, C, D, E, & F together 32.70					5.16	Total consumption 45.05		

The Pitometer observations provided information of great interest on the condition of the water mains as regards increase of resistance to flow with advanced age of pipes.

Selecting Tutton's formula (See Ph. Parker, Control of water, page 127).

$$V = C_1 \gamma^{\frac{1}{6}} \sqrt{\gamma \bar{S}}$$

where $C_1 = 158$ for new c. i. pipes.

126 ,, old, cleaned, Angus Smith coated.

87 ,, slightly tuberculated or with mud deposit.

= ·30 ,, heavily tuberculated,

the following values of the coefficient were found:

Mains	Age	Coefficient C_1
Tulsi 24″	45 years	90
Vehar 24″	37 ,,	110

An opportunity presented itself to compare different formulas for discharge, during the survey on the Tulsi 24″ Main, the result of working out the coefficients at two rates of flow being:

V Velocity feet per Sec.	S Hydraulic gradient.	C_1 Tutton's Coeffic.	Cx Hazen's Coeffic.	n Kutter's Coefficient.
3·65	00118	89·6	82·6	·0159
2·89	·0026	90·1	81·5	·0158

Note.- William Hazen's formula runs thus (Trautwine)

$$V = C_x \gamma^{0.63} S^{0.54} \times 0.001^{-0.04}.$$

At the time of writing this paper, the supply is considerably increased as compared with that of the year 1922 and it has almost approached a constant supply, which, it is expected, will be introduced in its entirety as soon as the new mains are completely laid and connected to the existing mains in Bombay.

With further necessary additions and alterations in the distribution system it is proposed to insure a daily supply of 50 gallons per capita throughout the town, with distributing mains capable of discharging the supply within a period of 8 hours (thus providing for maximum consumption) with a head of not less than 70 feet above the ground and also capable of discharging 500 c. ft. per minute at an elevation of 10 feet above the ground for fire

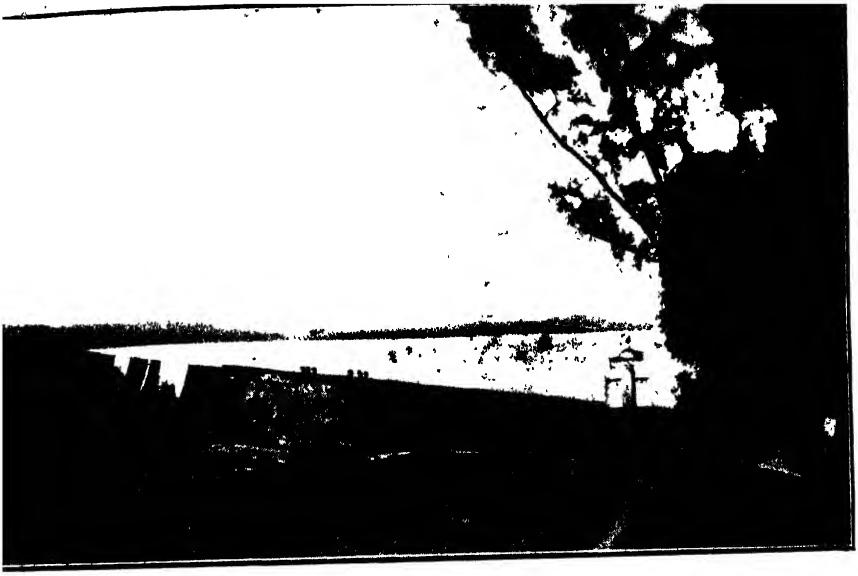
extinguishing purposes. The proposed remodelling of the distribution system will, it is expected, result in an entirely interlacing system for full security of supply, with distinct supply districts ensuring efficient control over distribution, divided into convenient meter districts for waste prevention purposes.

The whole work of the Scheme has been carried out to the design and under the supervision of Mr. H. J. Trivess Smith, M. I. C. E., M. I. M. E., Special Engineer, Tansa Completion Works, Mr. W. A. Niven, A. M. I. C. E., M. I. E. (Ind.) being at the time Municipal Hydraulic Engineer.

The author's thanks are due to Mr. A. W. Stonebridge, A. M. I. C. E., who has assumed the charge of the work on Mr. H. J. T. Smith's departure from India, for rendering assistance in preparing this paper.

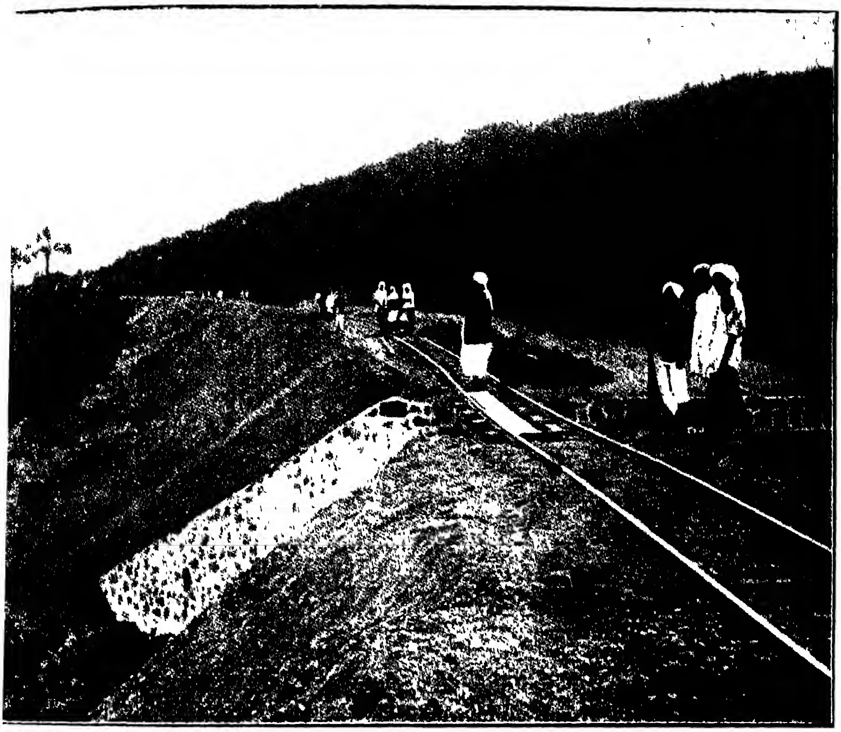
The Contractors for the manufacture and laying of the steel mains have been Messrs. Braithwaite and Co., Engineers, Limited, England, and for the preparation of the pipe track Messrs. The Tata Construction Co., Limited, Bombay.

The cost of the completed scheme is approaching Rs. $5\frac{1}{2}$ crores, of which about Rs. 1 crore represents the cost of the pipe track and about Rs. $3\frac{1}{3}$ crores that of the steel mains.

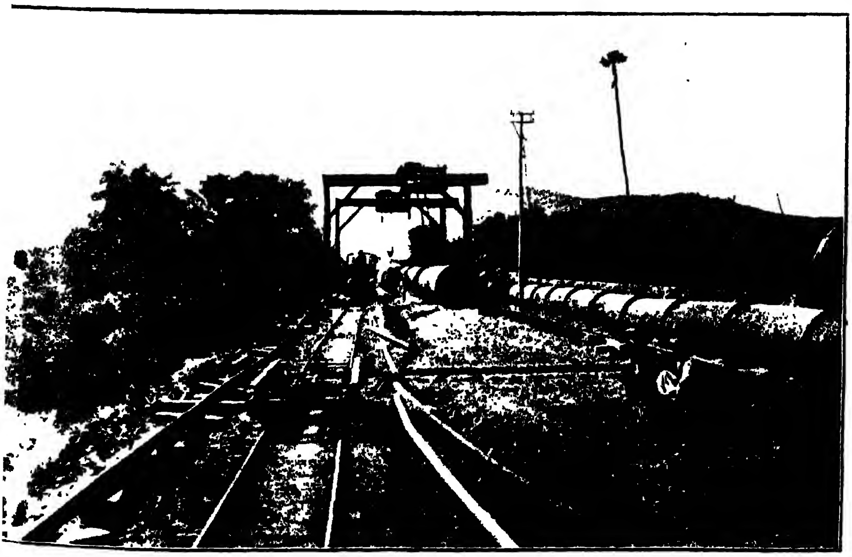


Tansa Lake and Dam.

Vehar Lake.



An Embankment Along the Pipe Track Near Bhandup About 40′ High.



Pipe Laying Outside Bombay Island.

PROKOFIEFF ON WATER SUPPLY OF BOMBAY

Plate No. 1.

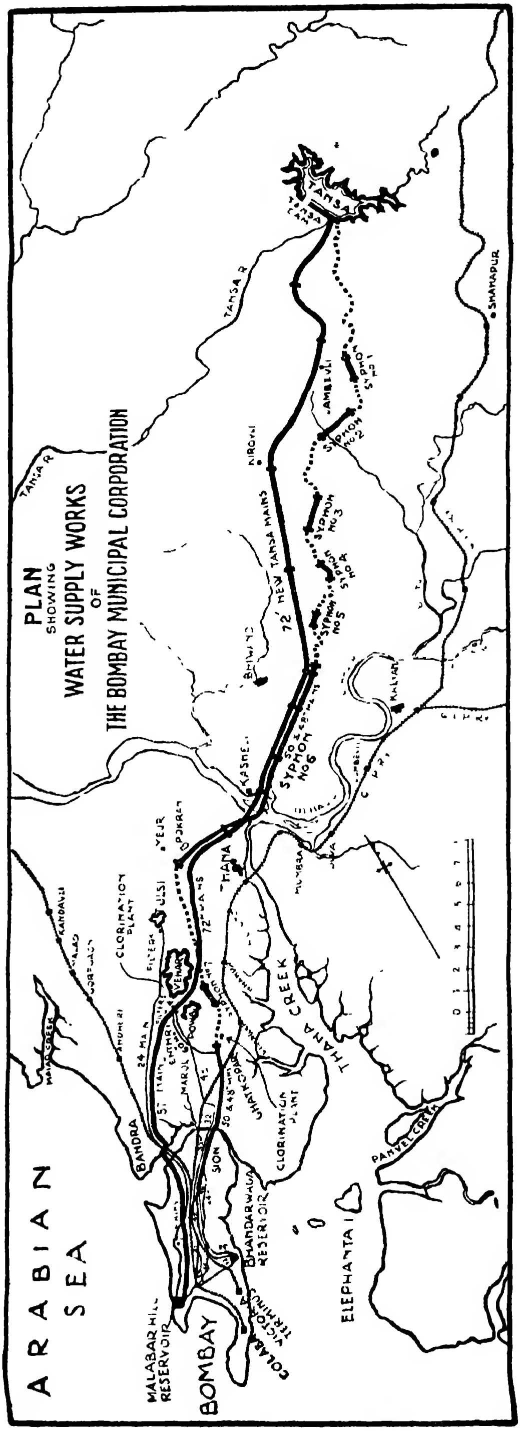


Plate No. 2.

SECTION SHOWING HYDRAULIC GRADIENT ALONG TANSA NEW MAINS
FROM TANSA TO BOMBAY WITH A BRANCH POWAI TO GATKOPAR

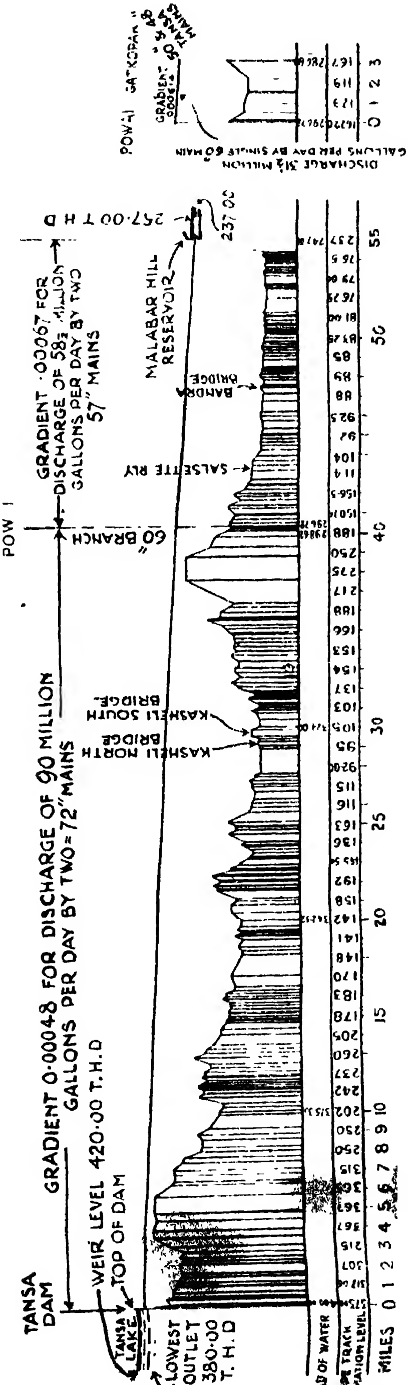


Plate No. 3.

MR. W. CLARKS DESIGN FOR TANSA DAM

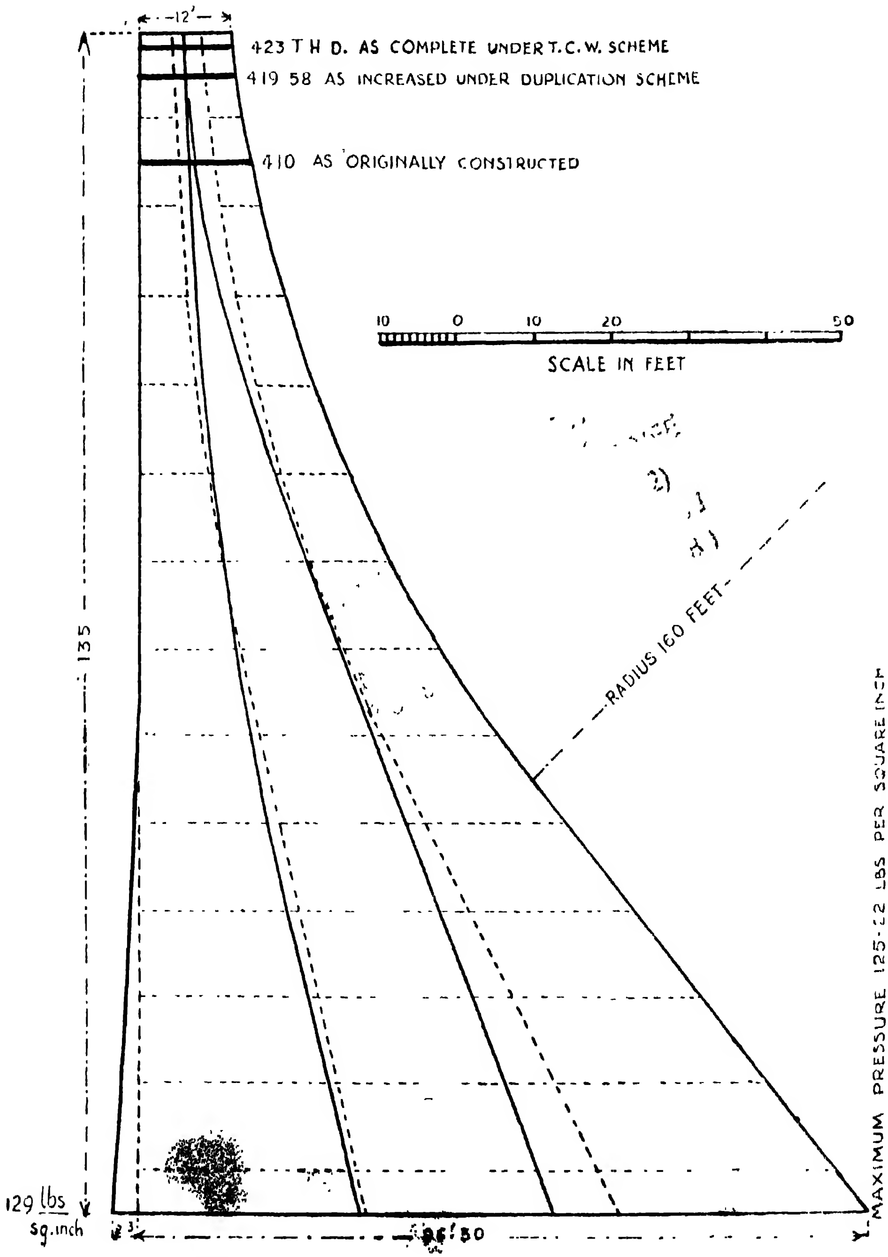


Plate No. 4.

DETAIL OF 5° BENDS FOR 57" PIPE

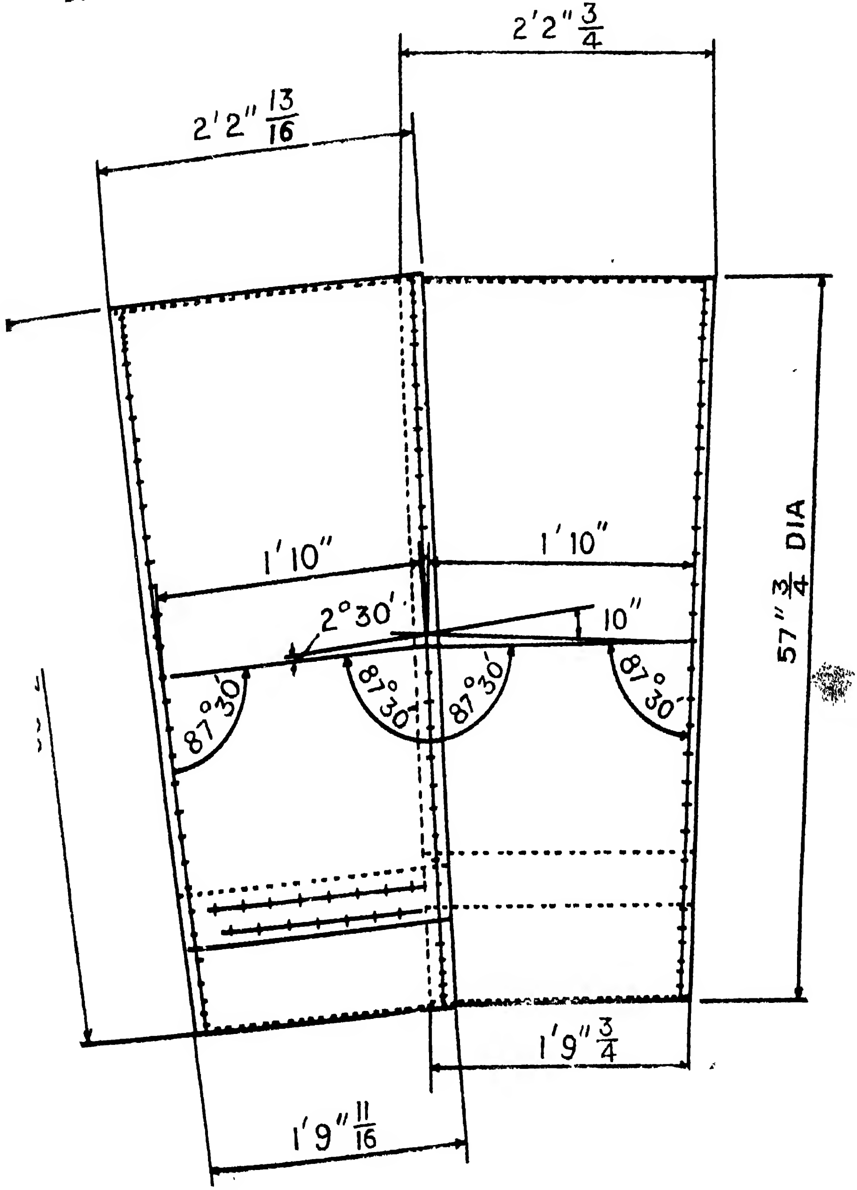
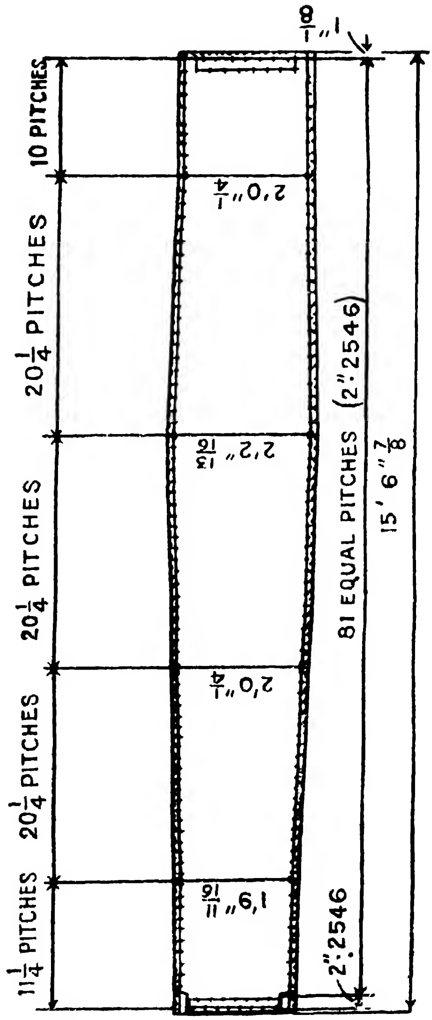


Plate No. 4.—(*Contd.*)



DEVELOPMENT OF OUTER PLATE

Plate No 4.—(*Contd.*)

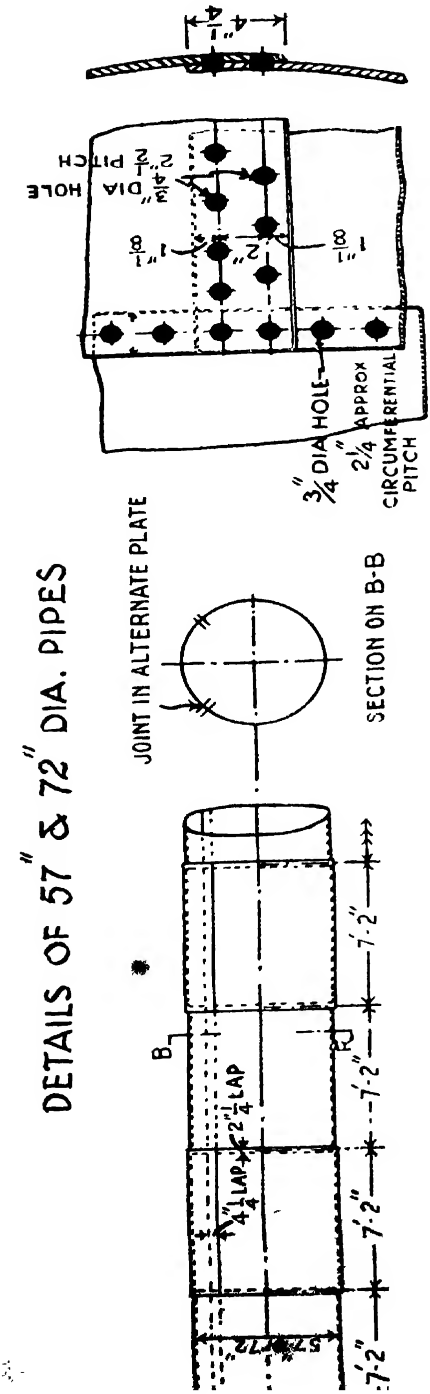
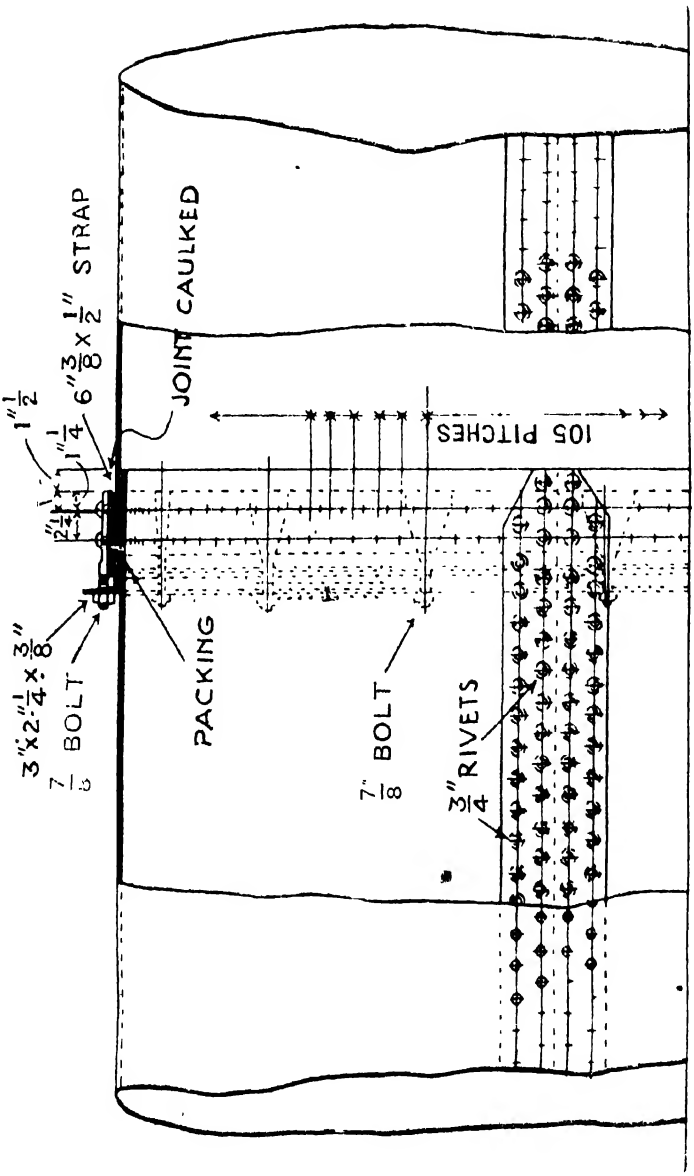
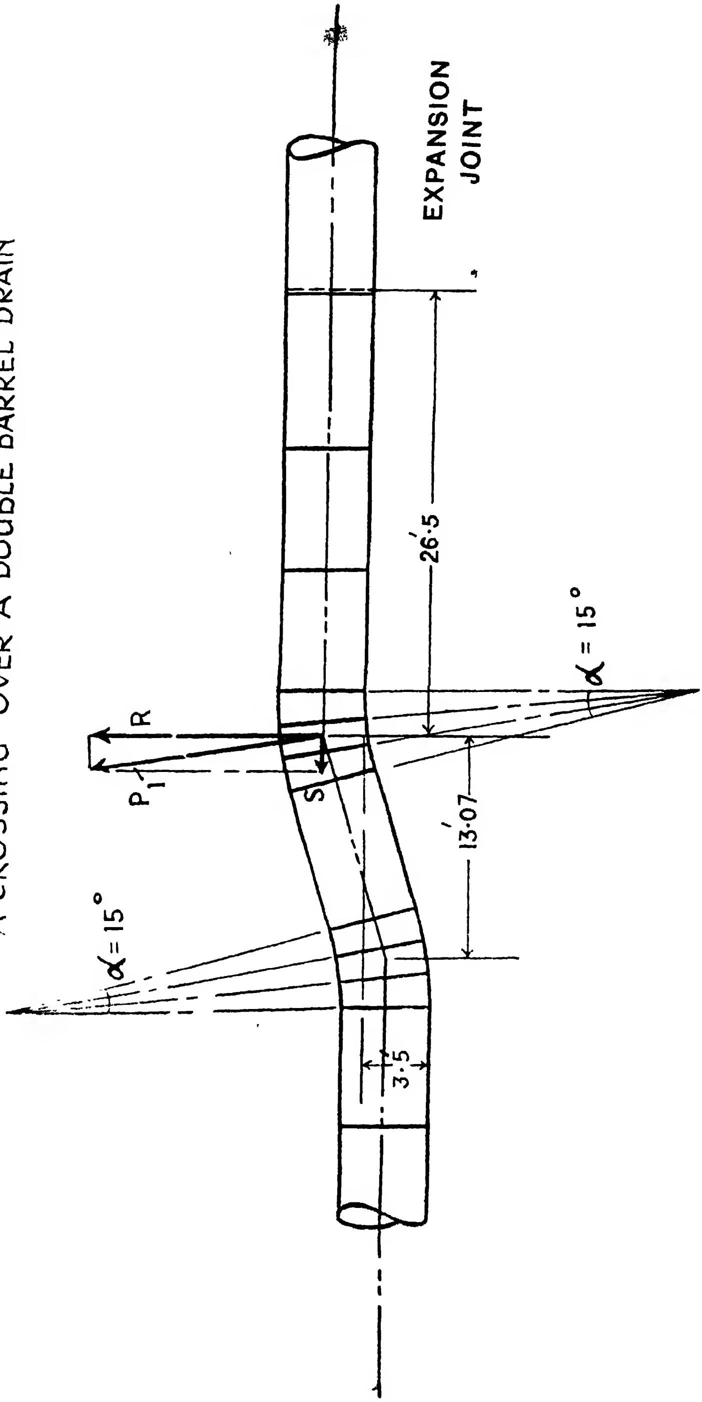


Plate No. 4.—(Cont



DETAILS OF EXPANSION JOINT FOR 72" PIPE

Plate No. 5.



A CROSSING OVER A DOUBLE BARREL DRAIN

Plate No. 5.—(*Contd.*)

CROSS SECTION OF DEEP TRENCHES

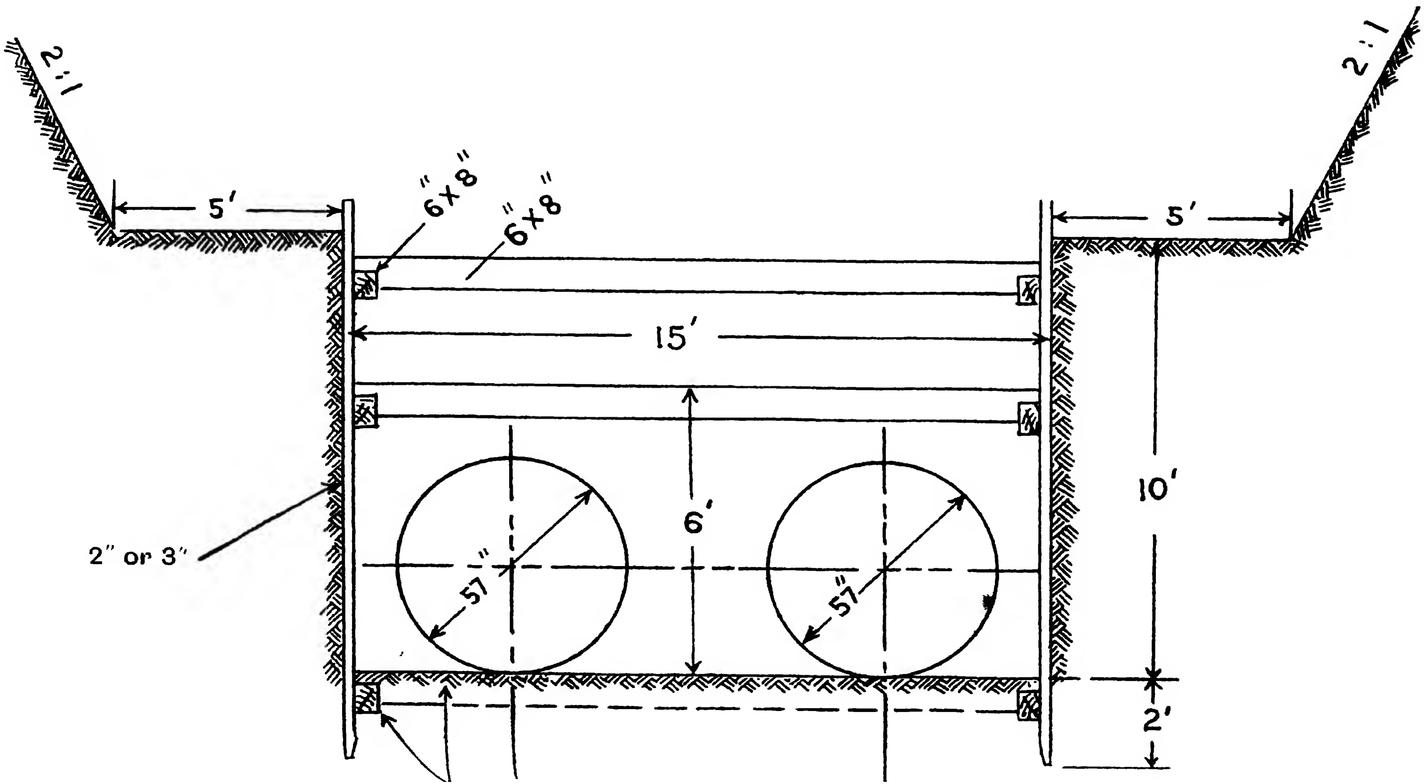
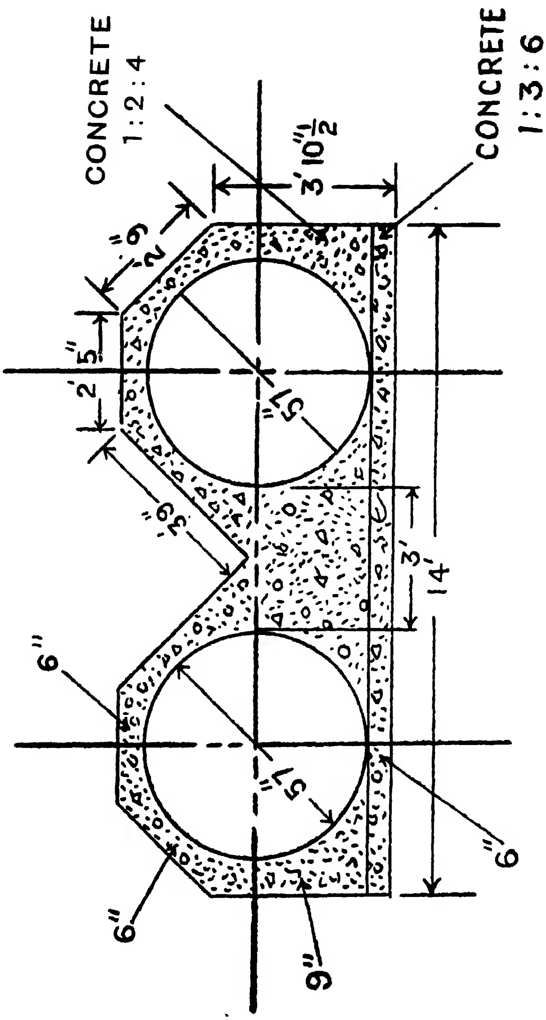


Plate No. 5.—(Contd.)

CONCRETE JACKETTING



DISCUSSION ON THE TANSA WORKS.

Mr. K. M. Kirkhope.—I think the author is to be congratulated on the presentation of a paper, full of interest and of much practical value to engineers contemplating or engaged in similar schemes. It is so full that it leaves little room for discussion. I, however, consulted this paper in connection with the problem of supply of pipes in which the engineer specified plates of boiler quality but failed to find the quality of plates used on the Tansa scheme specified though I imagine they are of A class steel such as are used in bridge construction though to minimize rusting ingot iron plates are being used by the same contractors elsewhere. I may say boiler plates were not supplied in the scheme mentioned, the engineer having to be content with something cheaper. I have had an opportunity of visiting this project, starting in the works of Messrs. Braithwaite at Muland where pipes were manufactured and after having seen the manufacture of these I proceeded along the pipeline to Bassein Creek and on to the bridge there. I was very much struck with the excellence of the work and with the excellence of the arrangements for carrying it out. I think it will generally be admitted as a tribute to the remarkable accuracy of modern fabrication methods that the plates should have come out from Great Britain fully drilled and scarfed, and that on being rolled into circular shape all the holes should have come together accurately.

The shipping of the plates flat was in this case done to save freight but under present conditions of tariff it would have been necessary to ship the plates undrilled and unfabricated in any way to save the high customs charges on fabricated steel. I think it is certain that it would have been cheaper to drill holes in India under present tariff charges than to have imported plates ready drilled.

Further the enterprise of the contractors in establishing a pipe making works has resulted in an additional bridge works being established in India on the nucleus of the pipe works.

I notice that painting in the field was done after mill scale had dropped off and I think this very sound. In steelwork contracts generally it is usual to specify that at least one or even two coats of paint should be applied in the works and in the case of imported steel-work it is usually found that most of this paint has

dropped off before the fabricated steel has reached site of works. In some cases, tendering firms have actually quoted lower rates if permitted to paint steel work after arrival at site, owing to the fact that they have in any case to repaint after arrival due to the damage done *en route*. It would probably be advisable in all cases to paint after arrival at site and give every opportunity for mill scale to be knocked off during transit and by the rusting which takes place during the sea voyage.

The expansion joints provided seem to be numerous and fairly long. It would be interesting if the author could state what movement has actually been found at these joints. This is always a problem in long supply pipes in India where temperature ranges are great, in some cases being more than double what they are in Bombay.

It is interesting to note the very heavy consumption of water in A ward and the small consumption in G ward and the author's note that, "whereas the supply was intermittent in A ward, it was constant in G ward." It has often occurred to me that the action taken when there is shortage of water by municipalities and others has tended rather to accentuate the shortage than to relieve it, for when the water supply is intermittent large quantities are stored and thrown away when the fresh supply comes on.

Again I would thank the author for his most excellent paper.

Mr. A. G. Khan.—With reference to Mr. Kirkhope's remarks regarding the advisability of painting steel work after arrival at site, instead of before despatch, he could not agree entirely with this opinion, as he considered it most necessary to paint steel work before despatch, with at least one priming coat. Mr. Kirkhope explained that the point he particularly wished to make in this connection was that it was no use painting steel work which had not lost its mill scale, as the latter, together with the paint on it, was bound to drop off eventually and the money spent on painting must, therefore be wasted.

Mr. T. A. F. Stone.—Also drew attention to the fact that no mention had been made in the Paper regarding the precautions, if any, that had been taken to ensure that the pipe line would not be damaged by the high pressures that might be caused by stopping the flow of water. He said that he had made some calculations of the pressures that would be developed by the closing of a sluice value in various times, using the formula—

$$p = m \times f = \frac{w}{g} \times f, \text{ where } f = \frac{v - u,}{t}$$

and found that, if the sluice valve was completely closed in 10

seconds, the resulting pressure would be about 900 lbs. per sq. inch and that, even it the closing of the sluice valve took 3 minutes, the resulting pressure would be about 50 lbs. per sq. inch.

Rai Bahadur A. Nanda.—Mr. Prokofieff's papers deals with a subject of great importance to a Hydraulic Engineer and the bold manner in which the whole scheme has been executed reflects the greatest possible credit on the Engineers responsible for designing and executing the same.

I was fortunate enough last year, when attending the Annual Session of the Institution, held in Bombay to go round some portions of this stupendous scheme in company with Mr. Stone Bridge. Mr. Prokofieff also was kind enough to show me the work of pipe laying within the city of Bombay, which was a highly laborious task requiring great care and forethought in view of traffic conditions and the numerous underground and surface services, which either crossed or coincided with the pipe alignments.

The table on page 2 is very instructive and useful. The rate of increase of population in Bombay as deduced from the figures of 1901 and 1926 works out to 2·6 per cent per annum—rate of increase in Lahore is 1·7 per cent per annum

Rate of consumption in 1926 went up to 50 gallons per head per diem and the total daily demand stood at 63 million gallons.

Now the water supply from Bombay is derived from three sources namely :—

1. Tulsi Lake
2. Vehar ,,
3. Tansa ,,

The first two are ordinarily capable of giving a daily supply of 14 million gallons and the Tansa Lake supply would now give 90 million gallons.

According to the consumption figures of 1926, there is thus a reserve of 41 million gallons in the Tansa Supply for meeting the increased demand in the future. This reserve would be fully utilized during the next 25 years, provided the rate of increase of population remains the same as during the past 25 years and the daily consumption per capita does not exceed 50 gallons.

There is no mention in this paper, however, as to whether house connections and private supplies in Bombay are metered or not

The number of house connections in 1926, was 31,868 and the people dependent on a single connection being 4 to 5, this accounts for a population of $1\frac{1}{2}$ lakhs nearly. Experience in Bengal and the Punjab shows that where the supply of piped water is plentiful, 1/3rd to $\frac{1}{4}$th of the total population derive their daily supply from house connections. There is thus great probability of the number of house connections in Bombay getting doubled in the near future.

This eventuality would necessitate the adoption of universal metering as an essential safeguard against negligent and wilful waste, if the Tansa supply is to meet the prospective demand during the next 15 to 20 years. The total cost of the Tansa completion works is not given in this paper, nor the annual cost of maintenance and of 1000 gallons of water piped down to Bombay. I however, understand that the total cost was in the neighbourhood of 3 crores of rupees.

Comparing small things with great we have got a scheme of gravity supply under contemplation in the Punjab namely for Ambala-water to be piped down 23 miles from the sub-artesian springs of the Ghaggar and we anticipated to supply water to the different consumers like the—Cantonment, the N.-W. Railway and the city at $6\frac{1}{2}$ annas per 1000 gallons.

The Tansa steel mains have been laid on the ground and taking into consideration the size of the pipes and the temperate climate of Bombay this was probably the best things to be done. The discharge of the mains has been calculated from Chezy's formula, which compares favourably with Kutter (value of N=013) Box and Fanning, while Professor Unwins own formula

$$S = \frac{0.0440}{D^{1.16}} \times \frac{V^2}{2G}$$

G for India = 32.125

allows for more than 30 per cent. extra incrustation losses. The Chemical analysis of water not being given in the paper, it is difficult to judge, which formula would suit the local conditions best.

The storage capacity of the city service tanks (50 million gallons) as against a total maximum supply of 90+14=104 million gallons is most satisfactory. Ordinarily 6 to 8 hours supply is stored to tide over the peak demand.

The author of the paper says that one of the striking differences in consumption between Wards A and G is due to waste of water in consequence of the supply being intermittent in A Ward while the supply in G Ward is constant. This is a valuable point

and accounts for the apparent paradox that consumption per capita is less if the supply is a 24 hours supply than would be the case if the supply was an intermittent one. Our experience in the Punjab is also the same.

The chlorination plant at Powai is a valuable adjunct to the whole scheme, it is worked for some months in the year, when the lake water is turbid and the fact that bacterial content is present even in 0.1 c. c. shows the necessity for such a plant and for the thorough disinfection of the raw water.

Mr. F. C. Temple.—The statement that disinfection alone cannot be considered as absolutely rendering water safe is one of the most important statements in the whole of the paper. It has been pointed out on more than one occasion to the Municipal Corporation of Bombay that they are running very considerable risks in chlorinating their water without first filtering it. At certain times the water undoubtedly carries a very considerable quantity of organic pollution and it is a well estblished fact that organic pollution can absorb very large quantities of chlorine without complete sterilization of pathogenic germs. So heavy doses of chlorine will inevitably make the water taste. This causes a danger when the population served is largely uneducated. For, to uneducated people water is water and fit to drink unless it is obviously dirty or has an unpleasant taste, and a water tasting strongly of chlorine will drive them to highly polluted water that happens to taste more pleasant.

That this is a very real danger is shown by the apologies for the taste of the water that appeared in Public Press at the end of July.

In addition to these risks there is a very appreciable risk of corrosion of pipes and fittings.

Mr. F. C. Griffin.—If the author had been present I would have liked to ask a question with regard to the temperature of the water. In page 82 of the paper it is stated that " on the whole length from Tansa to Malim and from Powai to Ghatkopar, the pipes are laid fully exposed, with the exception of the 57″ mains. Thus for most of the distance the pipes are exposed to the sun and it would be interesting to know whether, on a hot day, there was much difference betwen the temperature of the water entering the pipe line and that of the water flowing out of it.

I would also like to draw attention to the coating of the pipes. On page 89 it is stated that after caulking, the pipes were painted

with bitumastic paint,—on page 90 that the field joints were painted over, and on page 92 that no provision for additional protection of pipes laid under ground against corrosion or for additional strength were generally made. It appears therefore that except at the few crossings etc., where concreting was done, the pipes are protected with one coat of paint only. In the trunk mains of the South Staffordshire Mond Gas Co., steel pipes (Mephan Fergusson lock-bar pipes) were used, the pipes being in 28 feet length, and ranging from 4ft. diameter down to 21 inch. All these pipes were first dipped in Dr. Angus Smith's solution at the factory, then wrapped in brattice cloth, and dipped again in tar. On arrival at the trench side, any places in which the covering was damaged were repaired. After jointing, the collar and adjoining pipe was painted, wrapped with brattice cloth, and tarred. Where pipes were laid through ashes or old pit mounds, clay was carted to the site and the pipes were surrounded with 6 inches of clay puddle. The treatment of the Tansa steel pipe line seems to be very different to this, and it will be interesting to see what the life of this pipe line will be.

Mr. A. F. Wyatt.—The author states that bridging over the south arm of the Bassein creek presented a considerable problem in itself, which he did not propose to discuss.

A note on any special difficulties encountered and the means adopted to overcome them would be of general interest.

General.—Were there any special difficulties during construction. If so a note on these and how they were overcome would add greatly to the usefulness of the paper.

Mr. A. C. Austin.—In connection with expanding joints in the pipe line it would be interesting to know whether after a period of time these continue to function. Experience on Railway work would lead one to expect that the whole pipe line would probably to some extent creep, and that after a few months, or at any rate years, some of the expansion joints would be permanently extended to their extreme limit and others permanently compressed.

Mr. D. H. Remfrey.—The paper is one which might have been made very interesting if it had dealt with details and the difficulties encountered instead of merely sketching the general aspects of the case.

For example, the Tansa Dam although built of the full width for the intended final height in the first instance was not the full

height and has subsequently been raised 13′. Was there any difficulty encountered in doing this? Were any precautions taken in regard to variations in temperature between the old work and the part added. In the Assuan Dam the question of variations in temperature between the old work and the masonry added to raise the dam to its final level gave more food for thought to the designers than any other problem.

In this particular instance the problem is not of such magnitude nevertheless one would have expected special precautions to be taken and details as to what these were would be interesting. It would also be interesting to hear if there are any cracks in the newly added part, or any leakage through the joint between the new and old parts.

The question of the rain-fall and the run-off is one which is extraordinarily interesting.

Apparently with a mean annual rain-fall of 94 inches the run-off is 57.6 inches or 61 per cent.

The reservoir capacity is 80 per cent. of this run-off.

What however is likely to happen in a year of drought?

The present consumption appears to be about 65 per cent. of the reservoir capacity or a little more than 52 per cent. of the normal run-off.

In a year of minimum rain-fall the fall is given as 40 inches. The run-off in this case will be nothing like 61 per cent. and is more likely to be nearer 30 per cent. which would give considerably less water in the reservoir than was used in 1926. Ten or twenty years hence when Bombay has learnt to expect 35,000 million gallons per year it may suddenly find it has to do with half this amount. But it would only find this out when too late.

It would be interesting to know what studies have been made in respect to the reservoir capacity being reduced by silting. The question may not be a serious one in the Tansa Scheme but is a very great peril in certain schemes in India

The expansion joints and temperature effects in the pipe line are of primary importance. An expansion at the joints of 7½ inches is given by calculation allowing a temperature range of 90° Fahr. My own experience has been that engineering tructures do not expand or contract as much as they are expected to. For example on bridges mounted on roller bearings the expansion is often only half or one third of what is expected by calculation.

In the case of a pipe line which is not on roller bearings nor has any facilities for movement one would expect little movement at the joints.

Temperature stresses in the pipe and unequal stresses are also interesting. In bridge-work sometimes the temperature in a plate exposed to the sun is not so high on the upper or exposed side as on the underside. Again, the temperature between the upper side and the lower side of a bridge may very by 30°. It would be interesting to know how the temperature of the pipes vary and whether any allowance has been made for temperature stresses.

Further it would be interesting to know what the builders of this pipe line think of the subject of creep. Railway Engineers can tell us a good deal of the cost of rectifying creep in rails. What however would happen if the pipe crept badly? The weight per foot when full of water may be twenty times as much as a railway track, and the cost and difficulty of pulling back the pipe line may be more than twenty times as serious. The pipe is exposed to the sun for miles, and although not subject to the vibration to which a railway track is subjected it is possible that there may be difficulty from creep.

Finally the paper would be of much more value to the Engineering profession if instead of giving the total cost of the pipe line the Author could give the unit costs in detail—that is to say the details of how the cost per ton of pipe line work out as regards raw material, freight, handling charges, bending plates, fabrication, erection, rivetting, painting and overhead and supervision charges.

Mr. N. B. Wilson.—Re Testing. It is noted that no allowable leakage was specified. In testing will the author kindly say what actual leakage per mile or other unit of length of pipe was found? In Calcutta a length of 5,000 lin. ft. of 60″ diameter steel main has been tested when it was found leakage at the rate of 15 gallons per minute was taking place. No information, so far as I am able to trace, is available as to the amount of allowable leakage in large diameter steel mains.

Re: the floating of the empty pipes caused by monsoon floods, what steps were taken as to the placing of these mains at their original invert levels or whether they were allowed to remain in their uplifted condition. Did the upheaval of these pipes cause straining of the caulking and had they again to be recaulked.

In Calcutta during 1925 due to monsoon rain a length of 450 ft. of 60″ main was uplifted through a maximum distance of

2′-8″, no apparent damage has been caused although this pipe has not yet been tested. It is, however, proposed not to lower this portion of pipe but to fix an air valve on the highest portion of the pipe and have all joints caulked inside and out. This 60″ main lies between the two existing mains of 48″ and 42″ diameters with only 1′-6″ ft. clearance between those mains and the steel main on either side and is laid close to the edge of a large tank. Fears were entertained as to the safety of the existing mains but no damage has been done to them due to the upheaval of the 60″ steel main. The earth cover on this main at the time of the upheaval taking place was 2 ft. thick which was insufficient to balance the upward thrust of the empty pipe.

The collapsing of main pipes due to vacuum is not unknown. It would be of interest to know what leakage took place (if any) after pressing out the pipe to nearly its original section as explained by the author.

Chlorination.—The dose of 1.4 parts per million is fairly high. Have any complaints been received as to any "Iodoform taste" being detected by the consumers. It would be of interest to know what the cost per lb. of liquid chlorine is delivered in Bombay and from where it is obtained. Has any action yet taken place on the steel mains in spite of the precautions taken to get the chlorine solution well distributed in the main pipe and if so, of what nature and extent is this action?

Has there been any trouble with the valves on the cylinders containing the liquid chlorine sticking and preventing them being opened without risk to the operators?

The figures given by the author as to the consumption per head per day in the various districts are very interesting and point out very clearly that with a constant supply a much less consumption per head per day can be obtained than when the supply is intermittent.

The author has given a very interesting paper and is to be congratulated. The photos very clearly show the nature and extent of the work.

The author, in his reply, dealt with the various comments as follows:—

Mr. K. M. Kirkhope's remarks—The steel specified for Tansa mains was to be made by open hearth process, having a minimum tensile strength of 26 tons per sq. inch with an elongation of not less than 20 % in a length of 8 inch with a contraction of area at point of fracture of at least 40 %, etc.

As regards the controversies of opinion (Mr. A. G. Khan's remarks) on the advisability or otherwise of painting steel work before despatch, I would suggest that the priming coat in the shop may be of use for protection during transportation, provided the steel is previously cleaned of mill-scale by pickling and thoroughly cleaned of all dirt, oil and rust. Measurements of expansion due to temperature were actually taken and the co-efficient of linear expansion worked out, as far as I recollect, in the neighbourhood of 0.000007.

It is very interesting to note that Mr. Kirkhope substantiates my statement on waste due to intermittent supply as also do Mr. N. B. Wilson of Calcutta and Rai Bahadur Amarnath Nanda in their comments.

Rai Bahadur Amarnath Nanda's remarks—The domestic supply in Bombay is unmetered, while the trade supply is metered; the latter constituted about $\frac{1}{4}$ of the total supply in the year 1921.

Attempts were made to introduce meters for house connections, but the Municipal Councillors' sentiment against taxing the water supply prevailed.

The total cost of the scheme has been shown in the paper, namely, Rs. $5\frac{1}{2}$ crores (page 104.)

Mr. T. A. F. Stone draws attention to what is termed "Water-hammer." V. P. Marran's modern formula (see E. Wegmann's Book on Water Supply) runs thus:

$$P=0.0201\frac{L\times V}{T}$$

where L – length of pipe line in feet

T – time in seconds required to close gate.

Now, from actual observation, it takes 30-45 minutes to close a 36″ hand operated sluice valve, a Hydraulically operated valve of this size closes in a couple of minutes. Assuming for Tansa line - L=20,000 feet (distance from the lake to the nearest sluice valve); T=60 Seconds and V=3 feet per second. P works out at about 20lbs. per square inch; very different result as compared with Mr. Stone's rough calculations.

I would acknowledge with thanks Mr. F. C. Temple's substantiating my statement regarding disinfection by chlorine.

The chlorine plant described in the paper was an aftertought of the designer when he found that money was not forthcoming for his filteration proposals.

Mr. Temple's apprehension of the risk of corrosion due to chlorine has been completely confirmed by the failure of the pumps of the chlorine plant described, through corrosion of the valves made of "non-corrosive" alloy.

Mr. F. C. Griffin's remarks. I regret I could find no data in regard to the temperature rise of water flowing through the exposed mains. Experience in Bombay has shown, however, that the rise is very small and unobjectionable. Considerable length of all the supply mains in Bombay are laid exposed; they are 72″, 60″, 57″, 50″, 48″ steel mains and 48″ 32″, 24″ c. i. mains.

As regards coating of steel mains I am strongly of opinion that one coat of paint is very poor protection for the mains laid underground in Bombay.

Steel mains recently laid in Brooklyn (New York) were coated with two coats of bitumastic solution plus one of bitumastic enamel, the thickness of three exceeded 1/16″.

I regret I cannot satisfy Mr. A. F. Wyatt's desire to have a description on difficulties encountered in the construction of the Bassein Bridge. I endeavoured in my paper to dwell upon the problems of significance for water works engineering and especially referring to the works I was directly connected with.

As regards difficulties in general I hoped they were sufficiently referred to in the paper.

I must also apologise for disappointing Mr. D. H. Remfry in not describing difficulties where he expected them to exist.

To my knowledge temperature variations did not add much to the difficulties of connecting the old and new work in increasing the height of the Tansa Dam. Slight seapage is traceable in places along the line between the old and new masonry. Mr. Remfrey's question of future proposals is answered on the first page of the paper where it is stated that additional supply is proposed to be derived from Viterna River.

Silting of the lake does not present, to the writer's knowledge, a danger in the case of Tansa Lake.

As regards expansion in the steel mains due to temperature variation, the coefficient of linear expansion, from actual observations worked out in the neighbourhood of 0,000007. Unequal expansion due to exposure to the sun was very noticeable in the case of a vertically fixed air valve upon a curved portion of a main; the air valve inclined in opposite directions before and after

noon. Expansion joints responded satisfactorily in cases of unequal expansion.

Creeping of empty pipes was observed due to expansion, in some cases upwards of a slope, through jamming, towards easier responding expansion joints. Expansion joints excessively extended were satisfactorily rectified.

As regards unit costs in detail I regret that, away from Bombay, I cannot obtain the necessary information.

The above remarks answer Mr. A. C. Austin's questions. It should be noted that expansion due to temperature took place in empty pipes. Flow of water in the pipes prevented further influence of temperature changes.

To the writer's knowledge expansion joints on the Vehar steel 18″ main were caulked with lead, subsequent to the admission of flow of water.

With reference to Mr. N. B. Wilson's comments on my Paper on Tansa Completion Works, I have the following remarks to make.

Regarding leakage from the steel mains under test.

To my knowledge the New York Board of Water Supply specification for the recently laid 72″ steel rivetted mains in Brooklyn allowed total leakage from the mains tested under pressure of 300 feet column of water not to exceed 4 gls. per linear foot of pipe per 24 hours.

Actual leakage from the Tansa mains under test was not measured. All visible leaks through rivetted joints in the pipes, laid exposed, were satisfactorily closed and made tight. Leaks from the expansion joints were under the observation of Mr. W. A. Niven (Member), Hydraulic Engineer, Municipality.

The author has no data.

Referring to floating of pipes caused by monsoon, after the upheaval of the pipes no straining of the joints was noticed due, probably to responsive action of nearest expansion joints. The pipes went down after charging with water, helped by excavating underneath.

After the collapsed pipes assumed their shape no appreciable leakage took place through the rivetted joints. The nearest expansion joint suffered as explained in the paper; the author has no data as to the leakage through this joint.

The dose of 1.4 part per million is certainly very high and represented the maximum capacity of the plant described when treating 90 million gallons per day.

To author's knowledge complaints were received of the smell and test in the water treated by chlorine in Bombay with a dose even smaller than the above.

As regards disinfection of water by chlorine the author is endeavouring to introduce electrolytic chlorination in connection with the new scheme at Gwalior, as already practised in U.S.A. (Sacramento). The process is kown in India and promises to prove cheaper (provided cheap electric power is obtainable) and more convenient than that of liquid chlorine.

There is no doubt that a constant supply ensures less wastage of water, along with other advantages well-known to water engineers.

MORTAR TESTING

BY

S. R. KRISHNAMURTHY, Associate Member.

The strength of masonry lies, chiefly, in the mortar used, and although in important structures daily tests are carried out, there is no standard under which these tests are made, each engineer having his own method of preparing, keeping, and testing his specimens. Some engineers take the dry materials and make laboratory tests only, others take samples of mortar from pans, others from the mortar dumps on the work. Some mould the briquettes immediately the sample is taken, others wait a few hours before moulding, some add a little water if the mortar is too stiff to mould properly, some make tensile tests, and so on, so that although in the course of the construction of important works, I refer especially to Dam building, many thousands of mortar tests are made, the results cannot be compared owing to the different methods adopted in the preparation, preserving, and testing of the briquettes, and so valuable data is thus lost, and fresh arrivals have to begin anew.

The object of this paper is to point out the varying results that can be obtained by different treatments of mortar, and the briquettes prepared for tests, and to suggest to this Institution that a standard, both as to the preparation and testing of mortar, be laid down so that time may be saved, in the carrying out of experiments, by standardizing the procedure.

In this paper I have confined myself to the objects stated above, and have not dealt with the variations in the quality of the mortar owing to changes in the proportions and qualities of its ingredients, the relative merits of kankar lime, and fat lime with surki, the quality and quantity of surki to be used, the amount of water required, and the effect of increasing its quantity, and such other points dealing with the quality and design of mortar. These and similar subjects will be dealt with on another occasion.

It will be seen from the graphs and descriptions given below that, (1) the time of keeping the samples of mortar between grinding and moulding, (2) the method of preserving the briquettes, (3) the period between taking the briquettes from the maturing tanks and testing, (4) the height of the briquettes, and (5) size of the briquettes, have all a large influence on the results of the tests.

The tests, the results of which are given in this paper, were all carried out with lime and surki mortar, prepared under working conditions in power driven mills, in the proportion of 1 lime, 1 surki, and 3 sand (crushed stone) and unless specially mentioned all briquettes were 2″ cubes moulded in brass moulds and tested in compression to failure. The graphs will apply exactly only to mortar of similar composition, but I have no doubt that the general behaviour will be the same for all hydraulic lime mortars.

TIME FROM GRINDING TO MOULDING

Plate 1.

It frequently happens that mortar ground on one day cannot wholly be used on the same day, and a balance is sometimes carried over for one or two days from the time of grinding.

Tests were made to ascertain the extent of decrease in strength by so keeping, and the results obtained are shown on diagrams Figures 1 and 2. Judging by the results of the tests after 3 months, the mortar appears to lose approximately 10% of its strength regularly for every day it is kept after grinding, as will be seen on referring to Fig. 2, it is therefore unwise to keep this particular kind of mortar for more than a day after grinding, it being a quicker setting mortar than that made with kankar lime, the cause of the fall in strength is probably due to the disturbance of its initial set, as it is necessary to add more water and again mix before use. It may be noticed that the behaviour of the one day old mortar is very curious. It is actually stronger than fresh mortar after a week and a fortnight. The curves (Fig. 1) for fresh mortar, and mortar kept for 1 day cross at about 20 days. In order to test the accuracy of this point, similar samples were tested at the age of 20 days and found to give the same strength. I am unable to state the reason for this peculiarity, perhaps others may be able to suggest it. Each point marked with a circle on the curve is the average of four samples taken and tested on four different dates, four briquettes being used for each test. Thus every point given is the average of 16 briquettes consisting of four sets each of four briquettes. Each set was prepared from the same batch of mortar, portions being taken and moulded, (1) when fresh, (2) 1 day old, (3) 2 days old, and (4) 3 days old. Tests were not carried out for a longer period as it was thought that no engineer would care to keep mortar for more than three days after being ground. The mortar was preserved in a cool place, and kept damp by water sprinkled at intervals. A portion of the batch was taken for moulding each day and mixed, by a trowel, with sufficient water to bring it to the same consistency as it was when freshly moulded.

METHOD OF PRESERVING.

Plate 2.

Usually test briquettes of hydraulic mortar are put under water as soon after moulding as can be done without causing them to crumble, and till then they are kept in a moist atmosphere by covering with a wet cloth, or other means. This period generally varies from 24 to 48 hours from the time of moulding, according to the weather. Some engineers prefer to keep the briquettes always in a moist atmosphere. In order to ascertain the effect of the two methods of preservation, it was decided to make a set of briquettes from one batch of mortar and keep half under water and the remainder with the tops only exposed, in fine river sand, which was kept constantly wet by water sprinkled at intervals. The sand was not put in a tray but was spread on a concrete floor so that there was no standing water and the sand only was wet. These briquettes were taken from the sand two hours before they were required for test and immersed in water for this period so that both classes of briquettes for comparison should be in the same condition of wetness when tested, the necessity for so doing will be clear when the next section is reached.

It is seen from the graphs (Fig. 3) that mortar when kept in wet sand gives a much lower strength after a week than when kept under water for the same period, but the difference decreases quickly until it is nil at the end of three months. The reason for this behaviour cannot be stated with certainty until surki mortar is analysed at different ages and the chemical action between the lime and the surki is known. At present our knowledge of such action is not extensive nor definite but we know that Hydrated Calcium Silicate and Aluminate are the main constituents of the final product, and perhaps these form more quickly when the mortar is totally immersed. However, this test is of some practical importance as the briquettes in the wet sand represent the condition in the work better than those kept under water, masonry work under construction being only kept wet with sprinkled water and never immersed.

TESTING THE BRIQUETTES WHEN TAKEN OUT OF WATER, AND AFTER 24 HOURS DRYING.

Briquettes taken out of the maturing tanks and allowed to dry for some time before testing require a greater load to crush than those remaining in water until required for test. This difference which is about 44% after a week, decreases quickly up to a fortnight, and then more gradually until it is 8% after three months,

and nil after a year, as shown by the graph Fig. 4, each point marked on which is the average of seven separate samples, each of four briquettes. The rate of drying varies greatly according to the weather, the age of the briquettes, and the density of the mortar. It is preferable therefore, for the sake of uniformity, for briquettes to be tested immediately when taken out of the maturing tanks.

HEIGHT OF BRIQUETTES.

Plate 3.

Tests were made on Briquettes prepared from one batch of mortar and kept under similar conditions, but the heights of the briquettes were varied, thus, $2'' \times 2'' \times 2''$, $2'' \times 2'' \times 1\frac{3}{4}''$, $2'' \times 2'' \times 1\frac{1}{2}''$, $2'' \times 2'' \times 1\frac{1}{4}''$, and $2'' \times 2'' \times 1''$. The graphs (Figs. 5 and 6) show their comparative strength. Each point shown with a circle is the average of 16 briquettes prepared from four batches of mortar on four different days, there being 4 briquettes of each size from the same batch. The difference in the strength, between briquettes of various sizes, is great after a week, but decreases gradually until at the age of three months the $2'' \times 2'' \times 1''$ briquette is 1·98 times as strong as a $2''$cube. The reason for this big difference after a week and a comparatively small difference after three months is not quite clear. But it is not surprising that the strength of a $2'' \times 2'' \times 1''$ block is about twice that of a cube after three months. In a cube the shear due to the load, develops fully and thoroughly as seen in B plate 5, whereas in a block of the same section but half the height, shearing stress develops completely only at the fringe of the briquettes, for about half an inch width all round, as seen in A plate 5. This portion fails thoroughly, leaving a hard core in the centre. This is evidently due to the friction of the adjacent surfaces giving it lateral support.

Some engineers prefer to make the test briquettes of $2'' \times 2'' \times 1''$ or $3'' \times 3'' \times 1\frac{1}{2}''$ or $4'' \times 4'' \times 2''$ instead of cubes. Their contention is that joints in masonry are flat, and therefore a flat block will represent them better. But pressure on masonry joints is not always at right angles to the joints, which are sometimes in shear, and briquettes should be prepared as cubes for the results to be more in keeping with the actual stresses in the work.

EFFECT OF BEDDING MATERIAL.

Plate 4.

The faces of the briquettes which are in contact with the plates of the testing machine must be flat, and as far as possible smooth, so as to distribute the load equally, to obtain satisfactory results.

it is seldom possible to obtain such a surface whilst making the briquettes, and it is therefore necessary either to plaster subsequently the top and bottom faces, or use some bedding material when testing. The essential requirements of a bedding material are:

1. It should be rigid but sufficiently yielding to fill the inequalities of the surface without flowing, and

2. It should have sufficient strength.

The bedding material should not be so soft or yielding as to collect in the depressions in the surface of the briquettes, as this will cause lateral tension. The second condition regarding strength is not very important, as any solid material in such a thin layer, as is required for testing purposes, will withstand the pressure it will be ordinarily called upon to communicate.

It will be seen from Fig. 7 in which are given the results obtained with various bedding materials, that plaster of Paris gives the best results. It hardens quickly and presents a smooth surface, it is easy to apply and is not a costly material. A piece of paper, preferably an oil paper, is placed on any plane surface, (a piece of glass is the best), and plaster of Paris, mixed with sufficient water to give a stiff paste, is spread over it, the briquette is then pressed down on to the plaster, after a few minutes the briquette can be removed from the plate and the other face treated in the same manner. Plaster of Paris not only gives better results than neat cement, but can be applied just a few minutes before testing, whereas cement plaster must be put on some days before, so that it may set and harden sufficiently. This may also necessitate the keeping of the briquettes out of water for some time. Portland cement mortar gives results which are second best and only 4·8% less than those obtained with plaster of Paris, and it would be therefore better to plaster the specimens with neat cement where plaster of Paris is not available.

Mill boards come third in the order and give satisfactory results. Single boards 1/16 inch thick give better results than three such boards. The reason for this appears to be that the three boards yield a little too much, while a single piece yields less, but sufficiently to take up the inequalities of the surface and distribute the pressure. The briquettes tested were 2″ cubes and their surfaces fairly level. If larger cubes are used, or if the surface is very uneven, three boards give better results than one. When testing the briquettes without any bedding material, one set was tested on the sides, i.e., the sides which were adjoining the moulds when the briquettes were made were placed against the plates of the testing machine, another

set was tested in the same position as made. The idea was to take advantage of the smooth surface on the sides of the briquettes. From the figure it will be seen that the difference is only about 3·3%, but the strengths of the different briquettes when tested on their sides were more uniform than when tested on end.

Rubber insertion and motor tube rubber give very poor results and much less strength than when no bedding material is used. In fact they give only 50% of the strength obtained with plaster of Paris. The reason for this low result is want of rigidity. When applying the load the rubber is squeezed into the depressions on the surface of the briquettes and collects there, and when further load comes on it causes lateral tension with the result that invariably the briquettes cracked, with a loud report, vertically into two or three pieces. This can clearly be seen in C Plate 5. The motor tube rubber was torn, while the rubber insertion remained intact. All these briquettes failed suddenly but the results were very consistent.

The above tests were carried out with briquettes 14 days old and made of cement and sand in the proportion of 1 and 2. The specimens were prepared in four lots, each being tested in the several ways mentioned above. There were four briquettes for each specimen of bedding material. Thus each point given on the curve is the average of four separate tests with four briquettes for each.

The real strength of the mortar was about 300 tons per square foot, but to facilitate comparison, the strength with plaster of Paris is assumed as 100 and the other results are reduced correspondingly.

SIZE OF THE SPECIMEN.

Plate 4.

The use of 3″ or 4″ cubes is advocated by some engineers in preference to 2″ cubes as the size of crushed stone used as sand, generally in dams, is often 5/8 inch or more, but this is only a matter of opinion and there is nothing to show that we do not obtain the real strength of the mortar by using 2″ cubes. However, the difficulty of avoiding eccentricity in placing the specimen in the testing machine is greater in a 2″ cube than in a 4″ cube, as the percentage of eccentricity due to any displacement of centre of the specimen from the centre of the bearing plates is twice as great in a 2″ cube as in a 4″ cube, and for this reason it may be preferable to have larger cubes, but when 30 to 40 briquettes, have to be made daily, and preserved, as is being done at Mulshi, where all the tests referred to in this paper were carried out, 2″ cubes are more convenient as they occupy less room than the larger ones. Also

2″ cubes require a machine of much smaller power for testing. These are only practical considerations, but the graphs (Fig. 8) reveal another interesting feature.

It will be noticed that 2″ cubes show greater strength than 3″ cubes. The difference which is about 11·2 per cent after 7 days increases to 13·0 per cent after 14 days, and then quickly drops to 1·7 per cent after one month. It is not possible to explain this very peculiar behaviour of the briquettes in the absence of a thorough knowledge of the chemical action involved in the strengthening of the mortar as it ages.

METHOD OF FILLING THE MOULDS.

It is common knowledge of all engineers that tapping the mortar into moulds by means of any mechanical contrivance or with any heavy tool, tends to increase the strength of the briquettes. No regular tests were carried out to ascertain the extent of increase in strength with tapping because there is no standard tapping Machine or instrument, and the degree of tapping will vary with the person and the tool employed.

For preparing the specimens for these tests, the moulds were filled with mortar by means of a trowel which was passed through the mortar vertically several times. Then the mortar was tapped gently by a light piece of wood 1 inch square in section and about 1 foot in length. This tapping is not necessary for sloppy mortar, but when the mortar is stiff the moulds cannot be filled properly without a certain amount of tapping.

PERIOD OF KEEPING THE BRIQUETTES IN WET ATMOSPHERE BEFORE IMMERSING IN WATER.

It is usual to release the specimens from the moulds 24 hours after they are moulded and then to keep them in a wet closet or under a wet cloth for another day or two. This is necessary, particularly, in the case of slow setting mortar as the briquettes will crumble if immersed in water earlier. During the course of my tests, I noticed that the longer the briquettes were kept in a wet atmosphere before immersion in water, the stronger they were, compared with those immersed earlier. But there is a limit to this interval, after which there is no increase. I have not made tests to fix this limit definitely but hope to do so in the near future. I can say this much, that the interval, before the briquettes are immersed in water, which gives an increase in strength will vary for different kinds of mortar. It will be shorter for a quick setting mortar, and longer for a slow setting mortar.

CONCLUSION.

Some of the members may wish to know why I have not pursued any of these tests beyond three months. This is due to the very limited time at my disposal for this sort of work, the tests recorded above being all carried out in spare moments. The extent of work involved can be judged from the fact that over 1,700 briquettes were prepared and tested to obtain the results recorded, but I trust that I have made out my case sufficiently for the necessity of standardizing the methods of preparation, preservation and testing of mortars. The application of load. and speed of applying should, of course, be also specified. I intended carrying out some tests on these, but have not had the time to do so. For the tests in this paper a rocking plate with a ball and socket joint was used between the bearing plate of the testing machine and the briquettes, and the load uniformly applied on the ram at the rate of about 1,000lbs. per minute.

Before concluding I wish to say that my profound thanks are due to Mr. G. B. E. Truscott, the Resident Engineer, who very kindly permitted me to carry out these tests, and whose valuable advice and suggestions were always available to me. He also kindly helped me by testing some of the specimens when I was unable to do so owing to my absence on leave.

PLATE I

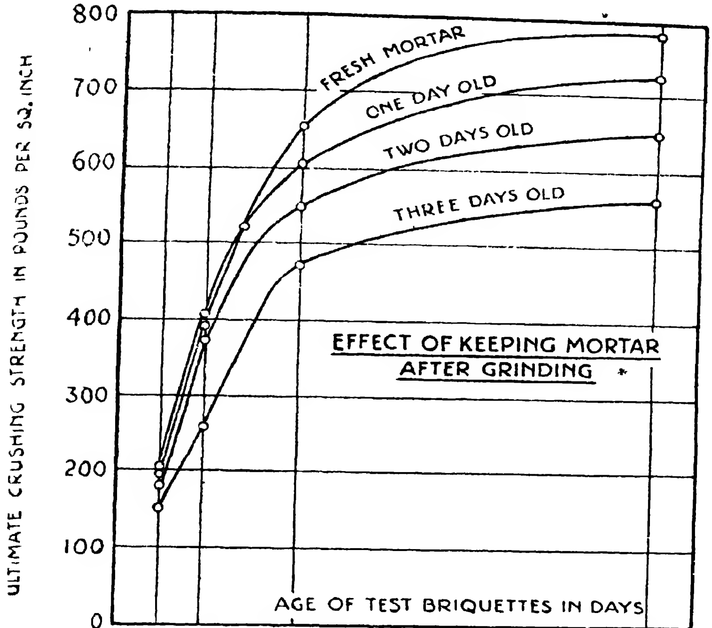


FIG. I

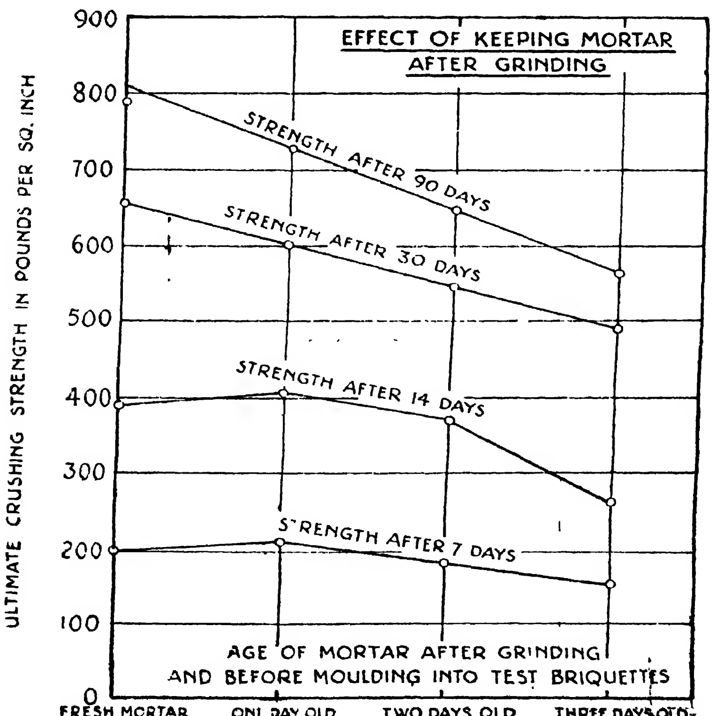


FIG. 2

PLATE 2

EFFECT OF KEEPING BRIQUETTES
IN WATER AND IN WET SAND WITH TOP ONLY EXPOSED

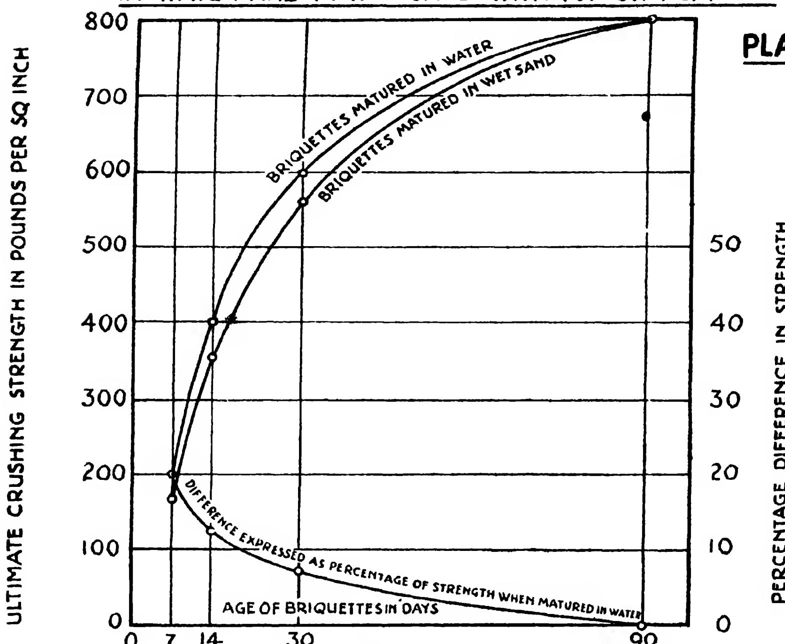


FIG. 3

EFFECT OF TESTING BRIQUETTES
IMMEDIATELY AFTER TAKEN OUT OF WATER & AFTER 24 HOURS AERATION

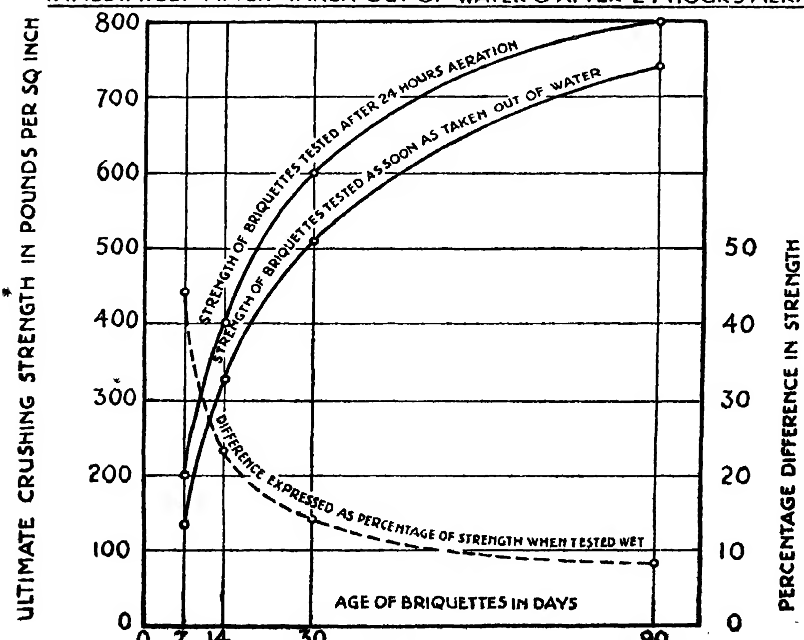


FIG. 4

PLATE 3

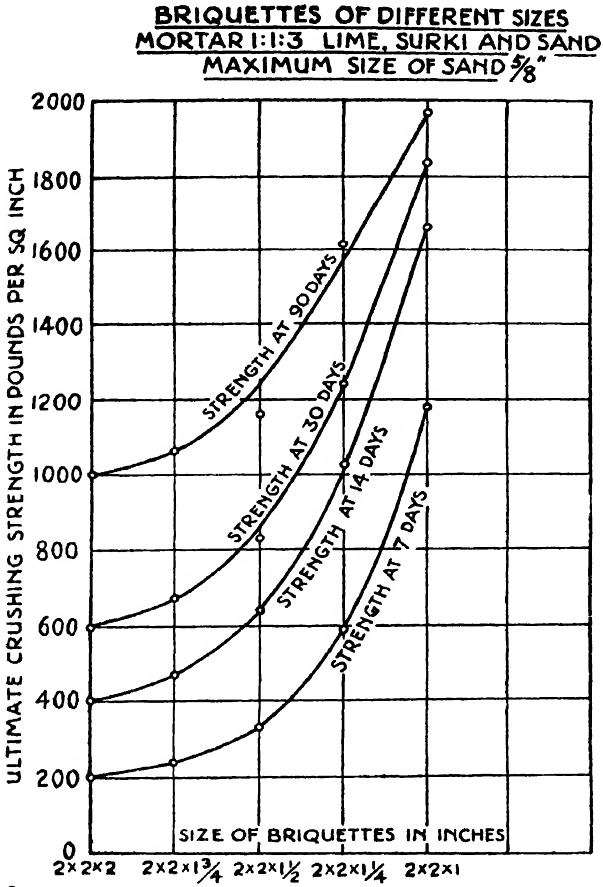
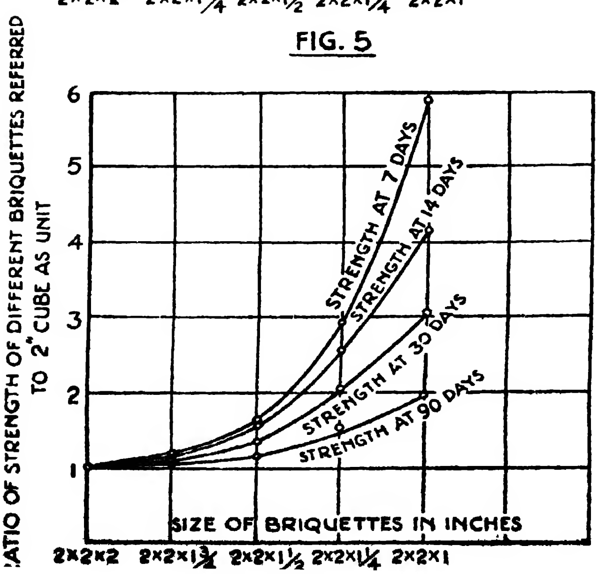

BRIQUETTES OF DIFFERENT SIZES
MORTAR 1:1:3 LIME, SURKI AND SAND
MAXIMUM SIZE OF SAND 5/8"
ULTIMATE CRUSHING STRENGTH IN POUNDS PER SQ INCH
2000
1800
1600
1400
1200
1000
800
600
400
200
0
STRENGTH AT 90 DAYS
STRENGTH AT 30 DAYS
STRENGTH AT 14 DAYS
STRENGTH AT 7 DAYS
SIZE OF BRIQUETTES IN INCHES
2×2×2
2×2×1¾
2×2×1½
2×2×1¼
2×2×1

FIG. 5


RATIO OF STRENGTH OF DIFFERENT BRIQUETTES REFERRED TO 2" CUBE AS UNIT
6
5
4
3
2
1
STRENGTH AT 7 DAYS
STRENGTH AT 14 DAYS
STRENGTH AT 30 DAYS
STRENGTH AT 90 DAYS
SIZE OF BRIQUETTES IN INCHES
2×2×2
2×2×1¾
2×2×1½
2×2×1¼
2×2×1

PLATE

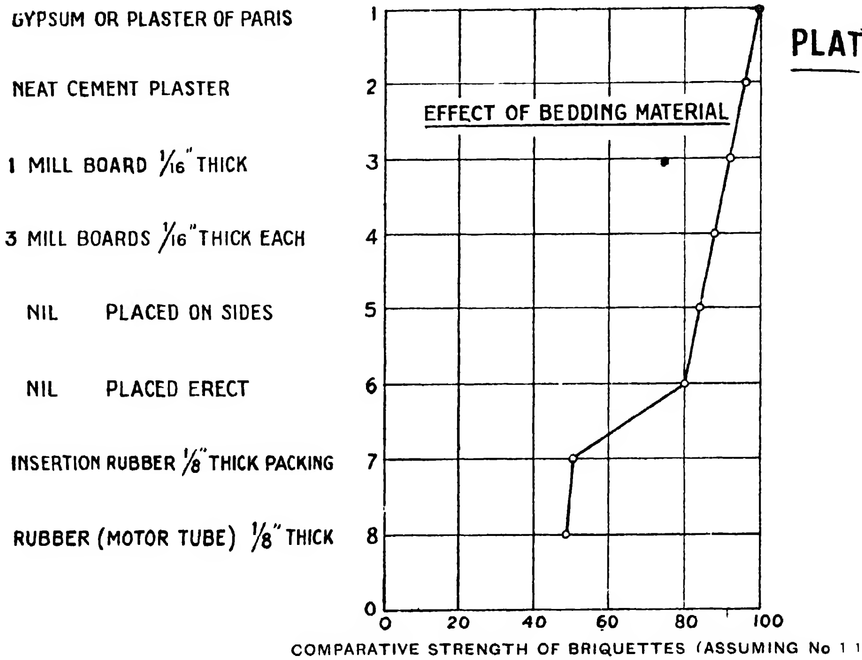


FIG. 7

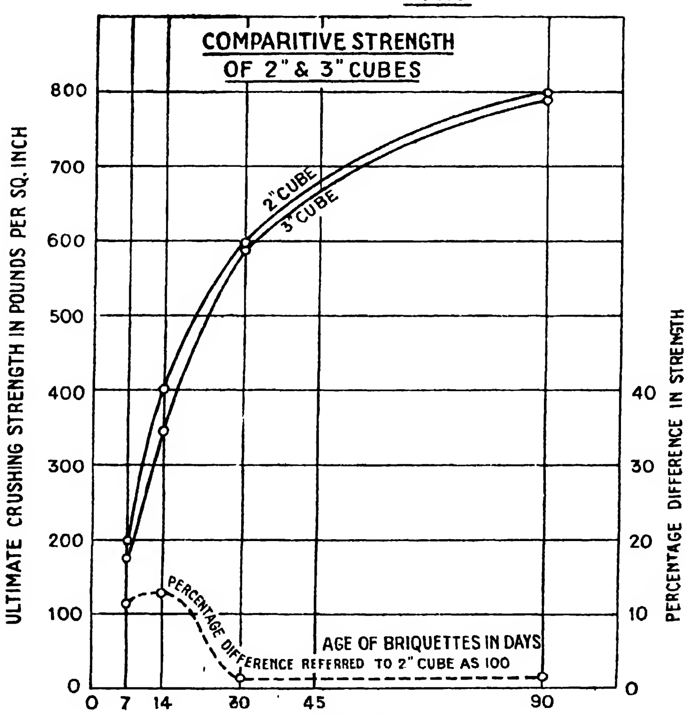
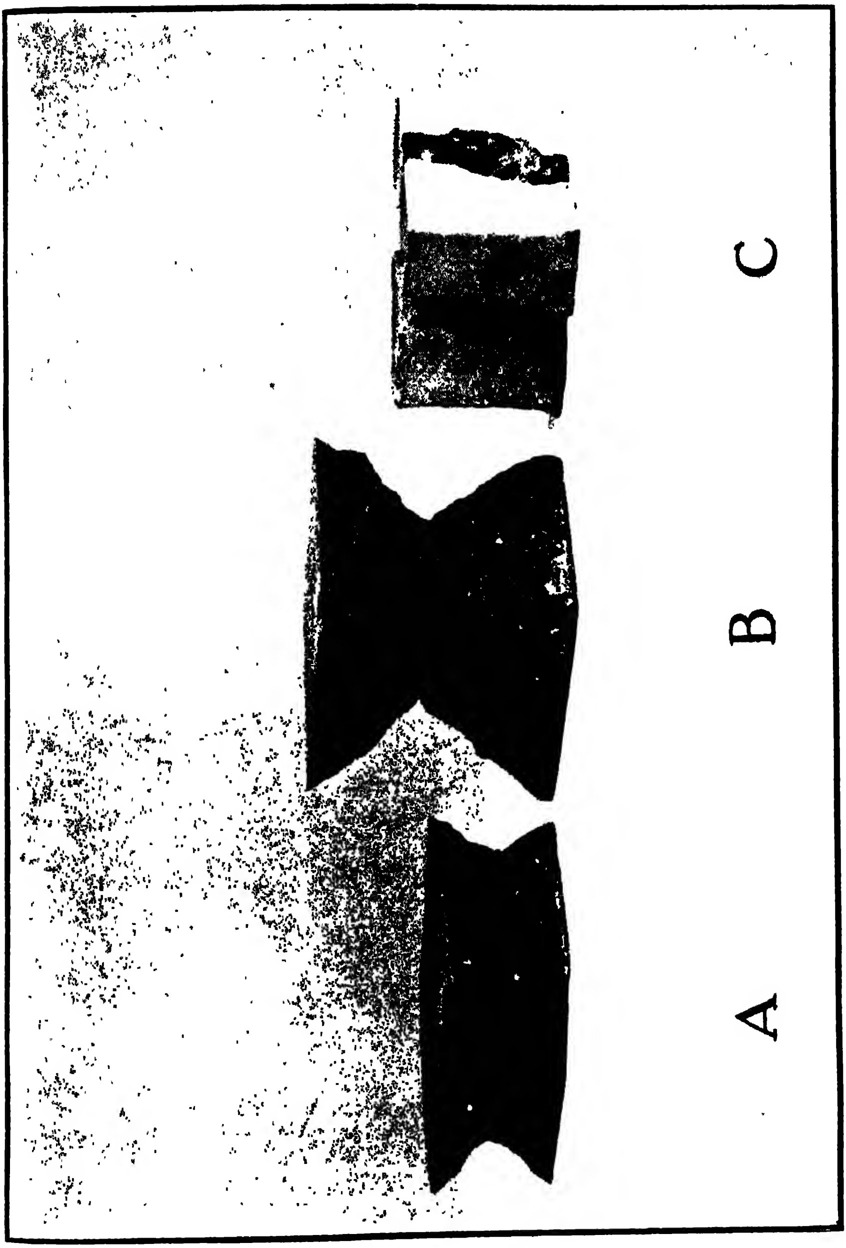


FIG. 8


A
B
C

by the East Indian Railway Company, and at Allahabad and Dhanbad, and later on at the Port Commissioners' Works in Calcutta. The tests he recorded were all made with Sutna Stone lime in various proportions of soorkey, sand, and cinders, to 1 of lime. Unfortunately his records give the tests of mortar briquettes after 6 months immersion in water and the chief fact emerging from his tests showed that after 6 months the mortar in some of the proportions was stronger than the brick itself. One interesting fact was that 1 of lime to 1 of sand broke at 64 lbs. tensile, while 1 of lime to 1 of soorkey broke at 316 lbs. Another remarkable result was that a very much weaker mortar, namely, 1 of lime to 2 of sand and 2 of soorkey broke at 282 lbs., while 1 of lime and 1 of sand and 3 of soorkey broke at 297 lbs. An engineer could therefore adopt either of these 4 to 1 proportions according to whether the sand or soorkey was the cheaper of the two, both of the mortars being found on actual test to be as strong as the brick itself. When cinders are used all ash has to be screened off to get rid of the fine white dust and we find that all unburnt and partially unburnt coal has to be removed by hand. The cinders are then ground fine enough to pass through a horizontal screen of 400 meshes to the square inch. The unburnt and partially unburnt coal is removed by women and children who actually scramble for it, and in fact ash picking vendors generally come forward offering to pay a purchase price for such.

The Chairman agreed with the Author that some definite arrangement should be adopted for each test. At King George's Dock we keep each briquette 4 days in a damp box (1 day flat in the mould, 2 days on edge in the mould and the 4th day out of the mould), on the 5th day the briquette is placed entirely under water and kept there for another 24 days, making 28 days in all. The air in the damp box is kept moist by a blanket, of thick felt, with its edges soaked in special water troughs. The mortar is taken direct from the vats. In spite of this uniform method of testing briquettes out of a random number of 340 tests the best tensile test per square inch after 28 days was 115 lbs. and the worst was 11 lbs. for a mortar consisting of 1 of lime, 1 of soorkey and 2 of sand. In another case taken at random of 14 tensile tests of neat lime after 28 days the best was 288 lbs. and the worst 52 lbs. In another random case of 365 crushing tests the best test of the mortar (consisting of 1 of lime, 1 of soorkey and 2 of sand) was 115 lbs. per square inch and the worst was 39 lbs.

An objection to the use of cinder mortar is the length of time it requires for setting. Nearly every engineer I have spoken to regarding tests of lime mortar have all had more or less the

same extraordinary diverse results, and on this account alone Mr. Krishnamurthy has unquestionably made out a case for some definite method of test standardization.

Mr. Richardson remarked that while he appreciated the amount of work involved in making the experiments on which the paper was founded he did not consider that the expenditure of time and money that will be required to lay down standardized tests for lime mortar would be justified.

The manufacture of materials used in lime mortar (lime, soorkee, etc.), cannot be standardized. The engineer has generally to use what he can obtain locally. The actual strength of lime mortar is not of much practical importance; all that is necessary to know is that the mortar will set and this can be determined by simple experiments at the site of the work.

He agreed with Mr. McGlashan as to the results of 7 days' test being conflicting and giving no real indication as to the future behaviour with the mortar. He referred to a case in the Darjeeling district where tests after a month, seemed to indicate that a mortar was worthless, which was found to be first class; so good in fact, that there was considerable difficulty in dismantling some of the masonry, in which it was used, when modification of the plans rendered this necessary.

He considered the experiment on the time from grinding to moulding to be of practical importance, quite apart from any question of standardization and said that tests he made on these limes himself, gave a similar result. If anything an increase of strength was found when the briquettes were moulded after mixing; this being probably due to obtaining denser briquettes owing to some of the excess water having evaporated.

Practically, all specifications provided that lime mortar should be used on the day when mixed; but even with vigilant supervision it is impossible to secure this being done and it will probably be a relief to engineers if they realize that there is a large margin of safety in this matter. He agreed that it would not be safe to use mortar more than three days old but it is generally the use of yesterday's mortar which it is impossible to prevent. Probably the safe limit is reached when water has to be added as the drying of the mortar may indicate that setting has commenced.

Mr. Atkins remarked that he was much interested by the subject matter of the paper, but still more so by Mr. McGlashan's description of the experiments made with different kinds of lime

mortar by the Engineering Department of the Calcutta Port Commissioners. His own experience was similar to that of Mr. McGlashan in that he had found that it was useless to place any faith in tests of lime mortar briquettes less than 28 days old. After experimenting with many different mixtures of lime and cement he had arrived at the same proportions as had been found successful in Madras by Mr. J. W. Madeley, namely, 1 part of cement, 1 part of stone lime, $1\frac{1}{2}$ parts of soorkey and 6 parts of sand. This mortar gave approximately the same results as a mixture of 3 parts of ghooting (Kunkur) lime and 2 parts of soorkey which had been occasionally adopted in Calcutta as a substitute for cement mortar for brick sewers. The objection to using ghooting lime in Calcutta was the difficulty of obtaining it freshly burnt. The combined mortar above described had sufficient cement to give it a fairly rapid initial set which safeguarded the mortar against disturbance while the lime was developing its strength.

Mr. A. F. Harvey—I think Mr. Krishnamurthy has done some very useful work in connection with Mortar Testing and all engineers in India, who are interested in that subject, must be grateful to him for what he has done. He has undoubtedly spent a great deal of time in carrying out tests under varied conditions, and must have spent even more time in tabulating and analysing the results of the tests and in converting them into graphs so as to make a comparison of the results of similar tests easy. In fact most of the graphs show at a mere glance exactly what Mr. Krishnamurthy wished to impress on his readers.

2. I must admit that I had no idea before I read this paper that the results obtained by testing briquettes of mortar could be affected to such a very marked degree by using different kinds of bedding material. Nor did I realise that, if I were comparing results I had obtained with those obtained by someone else at some other time, it would be essential to know whether he had matured his briquettes in water or wet sand, and also whether he had tested them a few minutes or some hours or a whole day after removing them from the water. There can be no doubt that it was necessary to draw attention to the fact that mortar testing should be carried out in accordance with definite principles and recognised rules, if engineers as a body are to benefit by each other's labours in this connection.

3. Unfortunately, although I think very highly of the work done by Mr. Krishnamurthy and am grateful to him for what he has done, I cannot help feeling that his Paper falls just short of

being really useful, because he has failed to follow his investigations to their natural conclusion by drafting proposed standard rules governing the procedure to be adopted when testing mortar. He has recognised the necessity for some such standardization and has suggested to our Institution that a standard should be laid down. I consider that he should have gone a step further and himself suggested a standard for acceptance by the Institution, after any minor alterations that might be considered necessary by the Council or a Committee appointed by them.

4. I have two reasons for regretting that Mr. Krishnamurthy did not suggest some standard procedure. The first is that, if he had done so, I feel sure that the majority of engineers in India would have adopted his standard for want of a better one, in case the Institution did not take up the matter and lay down any official standard. That would have ensured a certain degree of uniformity, whereas in the existing circumstances those engineers, who are interested in the matter, will each have to draw up his own standard procedure after reading this Paper, and I am afraid there will be no uniformity in the procedure adopted by individuals at their own discretion.

5. My second reason, for wishing that this Paper had included definite suggestions by the author, is that in all cases of drafting standard rules, procedure, specifications, etc., there are invariably two stages, namely, the spadework and the finishing touches. The former is what it is always most difficult to get done, and I think it was up to the author to do it in this case. If he had done it, it would have been a comparatively easy matter for the Institution to have put the finishing touches. It would not have involved much more than calling for opinions and criticisms from half a dozen members of a suitable Committee and co-ordinating the replies received. I trust that the Council of the Institution will eventually call on Mr. Krishnamurthy to do the spadework, and will follow it up by appointing a Committee to apply the finishing touches, so that we might have a recognised standard procedure in future.

Mr. E. G. Lazarus.—Would the author be good enough to amplify his charts by specifying the dates on which the "four different" tests were made and if possible give what he considers would be possible test results for other months in the year. Data regarding temperature and humidity would increase the value of the charts.

Mr. R. D. N. Simham.—In a Paper of this kind it would be always beneficial to furnish complete details of the figures obtained, so that, the range of variation of the figures from which

averages have been obtained, may be clearly seen and the efficiency and reliability of the results may be judged, before any remarks can be made on the graphs drawn with such average figures. Also, complete and detailed descriptions of the manner in which mortar briquettes were prepared, for every kind of test carried out, and the time or period taken for each operation until the specimen are brought to the testing platform, would be necessary.

The author's curves illustrating the compressive strength of mortar under different conditions of preservation, curing, wetting, etc., are interesting and a brief review of the facts which they tend to show actually, will be made hereunder, following the order adopted by the author.

In order to judge the deductions made by the author from Plate I annexed to his paper, it is necessary to know whether sufficient time was allowed for slaking of lime before using the same in mortar or whether the author considered that complete slaking would have taken place when the grinding operation was carried out; whether the mortar preserved after grinding, was protected from the atmospheric CO_2 or was left exposed to the interaction of air, but only kept in a cool place and damp by water sprinkled at intervals, what time the mortar was allowed to remain in the mould before immersing in water, what time was actually taken to mix mortar in the first instance, whether the briquettes were tested as soon as taken out of water in all the cases or after 24 hours aeration, etc. I think depending upon these conditions the results should be reviewed. Otherwise the deductions made are likely to be misleading. I would therefore like the author to furnish complete particulars as would be useful to all who may have the privilege to study the results of his researches.

With regard to the fall in strength of mortar, I cannot agree with the author's conclusion that the cause for such behaviour should be 'disturbance of initial set.' The weakening of the mortar may be due to the fact that the mortar kept for one day and more was not preserved from atmospheric interaction. By mortar being exposed to atmosphere the carbonation of lime should have taken place, which in its turn must have retarded and partially prevented the formation of calcium aluminate and silicate which alone go to constitute the strength of hydraulic mortars. Perhaps mortar that is preserved from atmospheric interaction will show different results altogether and the compressive strengths may not be decreasing in a manner shown in Plate I.

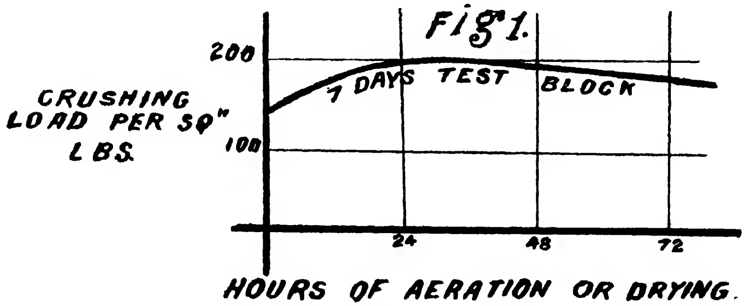
Method of curing.—The author uses the word preserving for 'curing.' There are several ways of hastening the complete formation of the hydrated chemical compounds in a mortar set. Sufficient water should be provided in the first place to facilitate chemical interaction. Depending upon the proper supply of water for hydration of the lime present in the mortar hastening of the formation of regular crystalline structure is brought about. So that it would appear, that when test briquettes are allowed to lie exposed to moist atmosphere without any wetting they will take a comparatively longer time to gain their maximum strength, as the rate of absorption of moisture sufficient for the chemical interaction can be only very slow; in dry atmosphere, the mortar cannot obviously obtain from the air any moisture, but on the other hand will loose its own water content and thus mortar cannot attain its due strength though it may be kept for an indefinite time. In a wet condition the rate of absorption is improved and the chemical interaction goes on without interference. In an immersed condition under water there is likely to be the same hastening of the chemical interaction, but in my mind it is doubtful whether mortar that is kept uniformly in a wet condition is not superior to mortar kept completely immersed in water, for similar ages allowed for the maturing of the mortar. In the latter, there is likely to be some weakening of the chemical interaction due to the presence of more water than what is actually required for setting and strengthening of mortar. But the author seems to prove an entirely different fact.

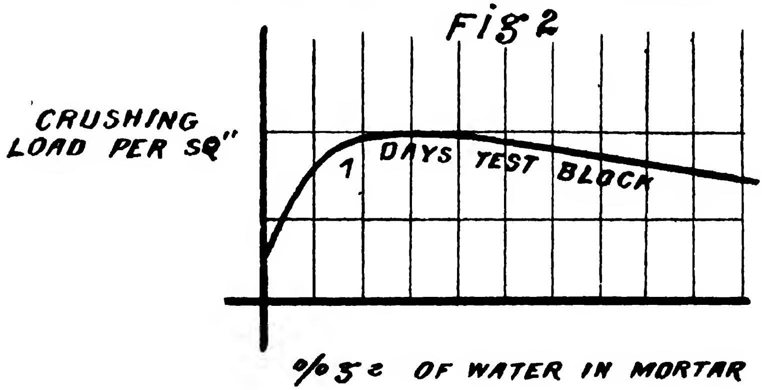
Moisture vs. strength of Mortar.—The results illustrated in figure 4 by the author in my mind establish very important facts, *viz.*, (i) The strength of mortar depends upon wetness condition or the water borne state or the moisture retained in the mortar. When excess water is present the mortar is less dense and consequently cannot support the full load. (ii) As the age of briquettes increases the moisture that can be retained by mortar or the wetness condition of mortar becomes reduced and in consequence the difference, between the strengths of mortar after 24 hours aeration and as soon as taken out of water, becomes reduced.

The neglect of the proper drying out or aeration of mortar to eliminate excess moisture is a frequent cause of its weakness and to ensure satisfactory strength, proper aeration cannot be too strongly insisted upon.

A certain amount of moisture in the mortar is quite essential to maintain it in a condition when it can support the maximum crushing load. The curve of strength *vs.* aeration period, or

strength *vs.* moisture in mortar will be as diagramatically represented in the marginal figures. The proper method of conducting the test would be to calculate the percentage of water





contained in mortar and find a relation of same to strength. Such a relation would determine the power of mortar to support load under different moisture or wetness conditions.

The above facts lead me to believe that briquettes tested immediately after taking out of the maturing tanks would not sufficiently demonstrate the quality of mortar under peculiar conditions existing in nature. Very often mortar crumbles down under dry atmospheric conditions at a very low loading.

Size of Briquettes. Provided we know in the first instance the law relating to strength and bearing area and depth of mortar, it would be immaterial to standardize the size of the test specimen. The graphs furnished by the author in Plate III are sufficiently

instructive in this regard. A general relation that seems to exist for any particular age of mortar may be deduced as :—

$$\text{Maximum crushing load} = \frac{\text{Constant} \times \text{Area}^m}{\text{Height}^n}$$

$$= \frac{k\,A^m}{d^n},\ \text{where k}$$

is a constant depending upon the age of mortar and might represent the crushing load when the block tested be one inch cube, m depends upon the evenness of the surface of bearing of the blocks and the eccentricity of the block axis and load axis and varies from 0·5 to 1·00, and n depends upon the compactness or angle of sliding and consequently upon the age of mortar.

When k, A and m are kept constant, then the ultimate crushing load would be inversely proportional to d^n. This is more or less illustrated by the curves given by the author.

By extending the same law for the curves arrived as stated above, the probable ultimate crushing loads may be calculated for mortars of thickness less than 1 inch. Assuming approximate laws to exist, the following values for crushing strength (per square inch) may be calculated:

For seven days mortar crushing strength $= \dfrac{1175}{d^3}$

„ 14 „ „ „ „ $= \dfrac{1650}{d^{2.4}}$

„ 30 „ „ „ „ $= \dfrac{1830}{d^2}$

„ 90 „ „ „ „ $= \dfrac{1970}{d}$

Area of Block.	Height.	CRUSHING STRENGTH AT				
		7 days	14 days.	30 days.	90 days.	
2 in. by 2 in. ..	¾ in.	2790	3290	3250	2650	lbs. sq. in.
Do. ..	½ in.	9400	8690	7320	3940	do.
Do. ..	¼ in.	75200	45920	29280	7880	do.

These results point out certain peculiar characteristic behaviour of materials under crushing stress and it seems necessary that

elaborate experiments should be carried out to find out how far the curves follow a definite law or laws that seem to exist between crushing strength and size of specimen blocks.

In the accompanying graphs the relative strength of briquettes or blocks have been illustrated in a manner which would be useful for study of behaviour of mortar. The same values adopted by the author in his figures, have been used in these. Taking the case of 90 days aged mortar the crushing strength per square inch, when its thickness is ¼ inch is likely to be as high as 7880 lbs. which is four times the strength per square inch when the thickness is 1 inch.

Owing to the unevenness of the end surfaces, there is difficulty in allowing the crushing to take place entirely over the section of the testing cube. It is on account of this that a compressive test is not generally preferred to a tensile test. But it is a very common practice to put the material to be tested in compression, in some plastic bedding. Plaster of Paris is the most usual material employed in this way for mortar testing. The occurrence of the well known double pyramid shape given by mortar compression test cubes on crushing is a clear indication that the strain is taking place in such a case in a perfectly equable manner.

The only thing that sometimes happen is that by adopting the shape of cubes on the specimen, the corners generally yield, first owing to the want of lateral support and therefore it seems necessary to make tests with cylinders instead of cubes. More uniform compressive results might be obtained with briquettes of cylindrical shape.

A detailed study of the relative effect of different end conditions would be of great value. Such study would lead to the establishment of some suitable standard method.

The nature of the bedding material, the force of friction, the lateral thrust developed in the bedding material when subjected to compression are factors which contribute to the weakness exhibited by mortar. With loose or elastic bedding material there is likely to develop two stresses as determined by Prof. Rankine expressed by the relation P1/P2 where P1 is the vertical force and P2 the horizontal force which is assumed to be less than P1. The horizontal force induces in the material a tensile stress, which we know in the case of mortar should be much lower than compressive stress. This explains why mortar fails under a very low load when the bedding material is plastic or loose or very elastic.

Sometimes the bedding material assists the mortar, to support a higher load than what it would be capable of bearing by itself. When the specimens are under stress their edges tend to move away from the centre, but the bedding material resists this movement and in this way becomes an external force helping the mortar to bear high resistance to crushing. A wet coating of Plaster of Paris or cement would permit the mortar to slide very much more easily than does a dry or set coating. Again the friction of the bedding material would tend to resist the lateral thrust developed in the specimen with the result that if the frictional resistance exceeds the compressive strength of the mortar a compression failure will result early.

Inasmuch as other factors other than pure campression enter into mortar strength, tests of tensile and sheer strengths of specimen should be also conducted. Detailed study and careful experimentation and analysis, and proper interpretation of the results of testing are required to develop limitations and to suggest modifications in existing practice and standardization of methods of testing.

The author is to be congratulated on the paper which is indeed useful in showing the various elements entering into the strength properties of mortar.

Mr. P. Natesa Iyer—The author points out in the first two paras of his paper the spasmodic methods adopted for testing lime and mortar by Engineers in this country, the difficulty experienced to get their results correlated due to each having adopted his own methods of testing, and the consequent desirability if not the duty of this Institution of this country to take up the task of standardizing the methods to be adopted for testing.

I strongly support the author in this and I would suggest standardizing committees being appointed by the Institution for such work, not only for dealing with mortar testing but for testing of all materials used on Engineering constructions in this country as in other countries instead of slavishly adopting the standard specifications of other countries without even examining their suitability to our country. It may be argued that it may not be necessary to traverse the same ground of testing materials which do not change their conditions in different coutries, for which such specifications as are international may be used, but before doing that, it is better that the various items of specifications of foreign countries proposed to be adopted are examined and classified as (*a*) wholly suitable or international (*b*) suitable by adopting a "factor" or "coeft." to suit conditions of this country, (*c*)

wholly unsuited and (*d*) items not in the foreign specifications but which find special application in this country.

For item (*a*) foreign specifications and testing rules may be wholly adopted with certain reservations regarding the effect of temperature, etc.

For item (*b*) tests should be carried out in this country to find out of the " factors " or " coefts." to be used.

Items coming under classification (*c*) should be ignored.

For items coming under classification (*d*) experiments on standardized basis should be carried out and standard specifications and testing rules drawn up for these.

The institutions are financed to some extent for such works by the respective Governments in other countries. I do not see why our Institution should not approach the Government to contribute for this useful work.

Roughly speaking, materials to be tested come under two broad classifications:—

1. Materials employed on a large scale for engineering manufactures and

2. Materials of local importance that may be more economically used than manufactured materials in Engineering works.

Regarding the first, Manufacturers as well as the users are interested in the testing of the materials; the former in ascertaining the qualities of the materials in order to be advantageously used for manufacture and in getting the best qualities of manufactured materials at the cheapest possible cost to command a flourishing sale in the market; the latter confine their testing to the specified strength of the materials supplied by the manufacturers and to see if they are suitable for the work on hand.

Materials of local importance if proposed to be used on works have to undergo all the testing of manufacturers as well as users.

It may not be difficult for the Institution to prescribe standard specifications to be adopted by the manufacturers or users if the following methods be adopted as is being done in other countries.

(1) Provide specifications and testing rules for different materials with regard to their innate strength such as tensile, compressive, etc., independent of the conditions under which they are used.

(2) to determine and specify " factors " for the strengths of each materials when used for work under varying conditions

The first is purely based on laboratory work and it will be imperative for the Institution to have a laboratory of their own as Institutions of the other countries have. The 2nd involves work both in the laboratory and in the field or if models based on field conditions can be made in the laboratory itself, it can be to a great extent attended to in the laboratory. Such a laboratory will have to be very large, and it may be better to leave such work to be done in the manufacturer's shops or laboratories or in the field of work. Determination of such factors is very important especially in such cases as the use of lime or cement mortar for civil engineering works, more so in masonry dam constructions, where the actual conditions within the dam body can only be vaguely visualised but cannot be even approximately ascertained by any direct methods. Merely testing the mortar briquettes under varying conditions of atmosphere or under water may give only the innate strengths of mortar for such conditions of setting under exposure to dry air, wet or saturated air or under water. The effect of horizontal and vertical pressures due to water pressure and such overload as comes on the elements of mortar in the body of a dam cannot be considered in briquette tests; nor is it known under what condition the consistency of masonry is in the enclosed body of the dam, whether it is in a plastic condition or in wet condition, nor can briquette experiments indicate anywhere near the actual conditions of strength if such materials are laid in the body of masonry and subject to the surrounding intensive pressures unless the dam gives way, and enables us to procure samples for testing, or unless some such methods as the following are adopted:—

1. Testing of briquettes under varying conditions and directions of pressure, as are likely to be met with in dam.

2. Making of big sized samples keeping them under the expected dam pressures for a reasonable time, removal of the pressures and testing of small briquette samples taken from almost the centre of the big sized samples for their plasticity and strength.

3. Making of small dam models with aggregates proportionally sized and used and tested at different sections. The above and other such suitable experiments to suit the expected pressures and conditions of the proposed dam will give factor or "coefts." to be multiplied to the values of strengths obtained from briquette tests and used with a greater degree of certainty for dam design than the indefinable or indeterminate so called "factor" of safety. It may be the work of scientists to ascertain the properties of materials, but it is for the Engineers to ascertain the factors to

be used for employing the materials to the existing conditions, with safety.

So standardization of specifications for testing should be framed with a view to correlate the results of laboratory tests of the Scientists to the actual conditions and determine "factors" to be applied. The time factor is also one of those that comes to play prominently between the time of sample testing of material and its use on work, as during that interval the condition of material changes due to partial setting or drying in air. There is also the "diversity" factor in the proportion of materials used on work which cannot be as rigorous as that used for laboratory work. There is also the time factor (1) in the grinding of mortar and in the time taken for use after grinding (2) in the period in which the mortar laid on the dam was exposed to weather before the next layer is laid on it.

There is also the other indeterminate factor of the rate of growth of load on the layers of masonry and its effect on the setting or resistivity of the material to such stresses.

So if experiments are carried out on well defined lines bearing the above in mind, to ascertain the different factors and if these results are correlated, it may be possible to draw up specifications for the execution of dam works, stipulating time limits for progress of different details of work, selection of material, etc. The Institution should formulate preliminary rules for such tests after discussion and circulate the same not only to the members but to the Government and the local bodies and undertakings concerned with construction works. Such a procedure is all the more necessary in the case of mortar tests as mortar is a commodity very largely used for construction works both public and private in this country.

There are only a few observations that I desire to make on the tests carried out and produced in the form of graphs.

The first is that only inferences can be drawn from the graphs such as from Figure 1 and 2 and freshly used mortar has a greater crushing resistance than mortar left unused for some time and then used; that mortar air dried after removal from water or wetting increases its strength and that a mortar briquette of half the thickness gives more than twice the strength of mortar briquette of the same thickness as width and give in 7 days more than the strength of the latter briquette of 90 days' life of setting.

With regard to the second inference I would advise the process of alternate wetting and drying in shade of samples and the study of such samples to see the effect of setting under such conditions;

with regard to the 3rd inference I do not know if such relations will hold for bigger sizes and especially to thicknesses of 6″ and more. If experiments give such favourable relations it will be useful for specifying the thickness of layers of concrete to be laid on dams. There is also one other inference that may be drawn from it, *i.e.*, that for quick construction of dams it takes a longer time for lime mortar to set than cement mortar and consequently the intervals between layers is longer.

Mr. Nataraja Iyer—The paper in question has made out a good case for standardising the preparation, preservation and testing of mortar specimens; but the methods suggested for these apply only to hydraulic mortar and not to fat lime mortar and the name of the paper might have been more appropriately qualified as hydraulic mortar testing. The reason is due to the important difference in the setting properties of hydraulic lime mortar and fat lime mortar. The former sets under water or in the presence of water and does not require the presence of air for its setting, the chemical action involved being rather complex with the formation of Hydrated Calcium Aluminate and Silicate, the former constituent being responsible for the initial setting of the mortar and the latter for the final setting. The clayey constituent of the hydraulic lime contributes to the formation of Aluminate and the sandy constituent to the formation of the Silicate with fat lime mortar; the setting is due to the desiccation of the mortar accompanied by crystallization of the resulting calcium carbonate which is formed by the chemical combination of the calcium hydroxide of the fat lime with the atmospheric carbon dioxide. For this formation of this calcium-carbonate, the simultaneous presence of both air and water is essential. The more slowly the process of desiccation and crystallization is allowed to occur, the better would be the hardening result. The above accounts for the fact that with fat lime mortar, the setting never occurs when the mortar is under water and requires the spraying of water. It is common experience with Engineers that when, in building masonry of fat lime mortar, the top course is edged with mortar and covered with 2 or 3 inches of water, the mortar under the water never sets till the depth of the water reduces to about half an inch.

2. The ordinary or commercial lime is of widely differing qualities, the shell lime being almost wholly of fat lime while the Kunkur lime or lime from limestone contains varying percentages of the hydraulic ingredients. With most of the ordinary lime mortars in use, what takes place during this setting is a combination of both the processes described above for hydraulic and fat lime mortars. When a lime is not sufficiently

hydraulic for a particular purpose say as in watery situations, it is rendered hydraulic by adding surki to the lime.

3. Referring to plate 2, figure 3 of the paper, it is shown how the curve of strength for briquettes kept under water is higher than the one for briquettes kept in wet sand. This phenomenon will be reversed with mortar of lime containing little or no hydraulic ingredients. It must be realised that a large proportion of the masonry structures which are actually being built are of mortar of fat lime, *i.e.*, lime with little or no hydraulic properties. To such mortar the methods of preparing, preserving and testing of samples would, as explained above, not be applicable and other methods will have to be devised and it is clearly not within the province of the present discussion to go into the details of these methods.

The Author's reply—I am glad that such a distinguished engineer as Mr. McGlashan agrees that I have made out a case for the necessity for the standardization of the method of testing mortar. Huge quantities of lime are being used every year in this country for constructional purposes, and yet Indian engineers know very little about their qualities, especially in conjunction with other materials such as surki, cinders, etc. Tests of lime mortars have been, and are being, carried out on many important works, and yet these cannot be compared to find out their relative merits, as the methods by which they are tested have no common basis.

I agree with Mr. McGlashan that tests after 7 days or 14 days are not altogether reliable, and that tests after 28 days should be preferred. That is so in cases where mortars of different compositions are to be compared, but when the cementing materials such as hydraulic lime, or lime and surkhi, etc., from the same sources are used, and the proportions of the different ingredients are the same, as is generally the case in big works, tests after 7 days give a fairly accurate indication of what the mortar will be like when it ages. It is also necessary to have tests made at as short a period as possible so that engineers may have an idea of the mortar that is being used in their work, tests after a long period make it too expensive to allow work done with a poor mortar to be rectified.

As has been pointed out by Mr. McGlashan, a quick setting mortar may show a higher strength after a week, but may show only equal or lower strength after a longer period. It is therefore advisable to rely on tests when the samples have matured for at

least one month when mortars of different composition, or containing different limes, are being compared. In fact, I am so convinced regarding this, after the large number of tests carried out by me, that for a series of comparative tests I am now making with lime and surkhi mortars I have entirely omitted the 7 days' and 14 days' tests and have taken a month as the minimum period.

With regard to the remarks of Mr. Richardson, I have to say at once that he seems to have misunderstood entirely the purpose of the paper. He says that the actual strengh of lime mortar is not of much practical importance. Probably he has had to deal only with small buildings where very low pressures are met with and possibly he was thinking of such erections when he made that statement. I have not concerned myself with such buildings but had in view engineering structures such as dams, bridges with large spans, etc., where often high pressures of as much as 10 to 15 tons per square foot have to be considered, and during the construction of which regular tests of mortar are made to ascertain the mortar is up to the designed strengh.

Mr. Richardson says that all that is necessary to know about lime mortar is that it will set. Nothing is further from the truth and I really am surprised that an engineer should make such a statement. I can show Mr. Richardson any number of samples of mortar which would set and yet be absolutely unfit for use on important structures where high pressures have to be withstood. The fact that a mortar sets is no guarantee of its strength whatsoever.

Mr. Richardson says that the expenditure of time and money which will be required to lay down standardized tests for lime mortar would not be justified. He adds that the manufacture of lime and surkhi cannot be standardized and the engineer has generally to use what he can obtain locally. Again he evidently has not understood the object of the paper.

I have neither pleaded nor even suggested that the materials used in lime mortar should be standardized, and cannot conceive any engineer doing so, nor that lime and surkhi mortar should only be used. I used this class of mortar for the purpose of preparing my paper as it is the mortar that is being used on the works on which I am engaged, equally satisfactory mortars can be obtained by using an hydraulic lime in lieu of surkhi and fat lime. I thought I had made this point clear in the third para of the paper. What I have, however, proposed is, as Mr. McGlashan has stated, that all lime mortars, from whatever materials they may have been prepared, should be tested under a standard method, so that the strengths of the different mortars used on various

important works may be comparable and all variations and uncertainties due to the different methods now adopted in preparing, maturing, and testing samples may be eliminated. In the paper I have tried to make out a case for standardization by showing the wide variations in strength that can be obtained with the same mortar when it is tested under different methods, most of which have been used by various engineers.

It is only to save time and money and not to spend more, that I have suggested that the Institution fix a standard method of testing, for it is only with such a common standard we can compare the strengths of mortars and so save time and money by eliminating all other methods.

To make the point clearer let me state an example. Suppose one engineer says he is using a mortar showing a strength of 100 tons per square foot after one year, and another engineer says that he is using a mortar which shows a strength of 80 tons per square foot after the same period. We cannot be certain that the first mortar is stronger than the second until we know,

1. Wherefrom the samples were taken in both cases, whether from the actual work, or directly from the mortar pans or whether prepared in a laboratory.
2. Whether the briquettes were moulded as soon as the samples were brought to the laboratory, or whether the mortar was allowed to stand for sometime before moulding, thus allowing some of the water to evaporate and the mortar to get stiffer.
3. What was the consistency when moulded.
4. Whether the mortar was rammed into the moulds or simply pressed in.
5. How the briquettes were preserved after moulding.
6. Whether the briquettes were tested wet or dry.
7. What bedding material was used.
8. Of what shape and size the briquettes were made, etc.

It is only on the above points I have suggested to the Institution to fix a standard and it will be readily seen that such standardization involves little or no expense.

Without information on the foregoing points no comparison of mortars can be made. We thus lose much of the value of the tests carried out by our predecessors or contemporaries. It is in order to enable engineers to get the benefit of the tests that are being carried out by others and thus save time, labour and money

which would otherwise have to be spent on independent and speculative research, that I have pleaded for standardization of the methods of tests, so that we can have a definite idea of the results obtained by different engineers. To make the point still clearer, I may say that if I am given any sample of mortar I can prepare two sets of briquettes and treat and test them in two such different methods, each method being that used on egineering works, but the strength of one set will differ from that of the other by as much as 50 per cent. or 60 per cent.

Regarding Mr. Atkins' comments, these are outside the scope of the paper, but I would say that it is no new thing to use ordinary lime mortar gauged with cement, the only difficulty in this country being that it must be used quickly to get the best results. I have complete a series of tests of lime mortar gauged with varying quantities of cement for comparison with ordinary lime mortar and hope to include the results in a further paper on the design of lime mortar.

I trust that most of the members will agree as to the necessity for standardizing the methods of testing lime mortar and that the Institution will move in the matter.

In reply to Mr. Harvey, I wish to say that I did not draft standard rules for the procedure to be adopted when testing mortar, as I wanted to leave this work to be done by a Committee of the Institution after taking evidence from other members who have knowledge of the subject.

However, as Mr. Harvey desires that I should suggest the standard to be adopted, I would mention the following rules as, in my mind, most suitable and these may be altered by the Institution agreeably to the views and expressions of other eminent engineers engaged or interested in the subject.

1. Mortar for test on important works shall be taken directly from the work and not prepared in office nor taken out of the grinding pans.

2. Mortar shall be moulded into test briquettes as soon as it it is brougth from the works and without adding water or letting it dry. The time from taking of the mortar to moulding shall not exceed one hour.

3. Mortar shall ordinarily be tested to destruction in compression and where tensile tests are preferred, these may be done, if possible, in addition to compressive tests. The briquettes shall be cubes preferably 2″ in size, and moulded in metal moulds of

correct shape placed on a level metal base. The top face of the briquettes should be finished smooth and level by means of a trowel.

4. While filling the moulds mortar may be pressed by fingers to ensure proper filling, no mechanical tapping being allowed. When the moulds cannot be properly filled by pressing with fingers, the mortar may be tapped by means of a light piece of wood.

5. The briquettes shall be released from the moulds after 24 hours and shall be immersed in water and kept there until required for test. If the briquettes will not hold under water after 24 hours and will crumble, they may be kept in a moist atmosphere for the minimum period necessary to enable the mortar to harden sufficiently and remain intact under water.

6. Briquettes shall be tested wet as soon as taken out of water.

There are two other chief points on which the Institution will have to express itself (1) The use of a rocking plate to give proper bearing to the briquettes, take up any inequality in its shape and ensure central application of the load, and (2) The use of a suitable bedding material. Opinion will differ on this second point. Those who test only a few briquettes occasionally will like to face these with cement or plaster of Paris whereas those, who have to test a large number of briquettes daily as it is being done here, will prefer the use of mill boards and I have been using only mill boards as they are convenient and require very little time. Also there is only a small difference between the results obtained with mill boards and those obtained with cement plaster.

No reasons are stated here in support of the rules mentioned above, as such reasons are sufficiently indicated in the paper and as I wish to be brief in the reply which is already lengthy.

In answer to Mr. Lazarus, climatic conditions have no doubt some effect on the strength of mortar but the subject has not been studied sufficiently to offer definite conclusions. It is known, however, that mortars matured under higher temperatures show greater strength than those kept under lower temperatures. This question of the effect of temperature and humidity has been omitted from this paper for the obvious reasons that such climatic conditions cannot be standardised.

The mortars for the tests referred to by Mr. Lazarus were made within a few days of one another and the briquettes were matured under identical conditions to avoid complications in the results due to the effect of variations in climatic conditions.

Mr. Simham has given himself a great deal of trouble in writing his comments, much of which could have been saved had he confined himself to the objects of the paper, as he deals with subjects far outside its scope. Many of his remarks too are in the nature of deductions from the results recorded. I set out to show the variations which can be obtained by preparing maturing and testing mortar briquettes and, having done so, suggested that a standard be laid down by the Institution to regularize the procedure. Mr. Simham's comments would possibly be of some use to the Committee which I trust the Institution will form.

I cannot imagine the use of supplying the figures of the test on each individual briquette. It may satisfy Mr. Simham to know that any briquette giving a variation of more than 8% from the average was ignored.

The lime was made from Shahabad lime stone and thoroughly slaked before mixing for mortar.

The method of preparing and testing the briquettes is outlined in the paper and unless definitely stated to the contrary, was identical for all samples. Mr. Simham does not consider that a definite standard can be determined by a few experimentations, neither do I, that is why I used over 1,700 briquettes to obtain the results recorded and few as the various methods used may be, the results conclusively prove that standardization is necessary. There are many other methods which could also have been used, but would have done nothing further to prove my case, and I cannot see of what additional practical use those suggested by Mr. Simham would be. Some of his views, however, require correction and appear to emanate from the mind of a theorist who has had little or no practical experience in handling or testing mortar.

Dealing with plate 1, he says that the decrease in strength must be due not to the disturbance of initial set, but to the mortar being exposed to the atmosphere resulting in carbonation of the lime. The experience of several engineers, and the examination of many old structures show that the process of carbonation of lime is very slow and is only superficial to start with. It has been recorded that even in walls of ordinary thickness carbonation of lime in the interior had not taken place even after the lapse of several decades. But Mr. Simham tells us that in three days carbonation of lime should have taken place to such an extent as to cause a drop of 30 per cent. in the strength of mortar. His suggestion to keep the mortar free from atmospheric interference and then test it, is equally unpractical such a test is of no use whatsoever

to the engineer who has generally to leave unused mortar exposed to the air.

Methods of preserving:—Mr. Simham would use the word "curing" instead of "preserving." But I confess my inability to see any correction or improvement in it, and feel no regret for having used the word "preserving."

While traversing the section "Moisture *vs.* strength of mortar" he shows a certain confusion of thought by mixing up the moisture contents of the test briquettes at the time of testing with the water contents of the original mortar at the time of moulding. I can see no other reason for his statement that when excess water is present the mortar is "less dense" and consequently cannot support the full load. The real cause of the lower strength shown by the wet briquettes is not explained by his ingenious theory of density, or crystals, but the lower strength is due to the internal pressure set up by the water particles in the mortar causing lateral and tensile stresses. It may also be due, to some extent, to a sort of lubricating action of water on the internal shearing planes. Another possible reason is that moisture softens the particles of mortar and causes reduced internal frictional resistance.

His graph in figure 1 is not correct. He has shown the maximum strength as obtainable after 24 hours aeration, whereas this period is controlled chiefly by weather conditions and ordinarily it is much longer. I do not give exact figures here as I have not yet completed them for publication.

His analysis of the results shown in plate 3 is interesting but I do not see any reason for the "elaborate experiments" to find out how far curves for various heights of briquettes follow a definite law or laws, all that is required is to standardize the size of the mould to be used. His suggestion for the use of cylinders instead of cubes as testing briquettes is commended for consideration. I may also add that in the United States of America now-a-days test blocks of concrete are generally of cylindrical shape.

Regarding Mr. Simham's preference for tensile instead of compressive test. Mortar is intended for use under compression only and it is certainly more desirable to have it tested in compression to ascertain directly its bearing power rather than to test mortar in tension and then apply a formula to find out its compressive strength, this formula varying for every different kind of mortar. There is also a practical difficulty in that crushed stone is generally used on big engineering works in lieu of sand, and mortar prepared with this usually has pieces of stone up to 5/8 inch in size and so

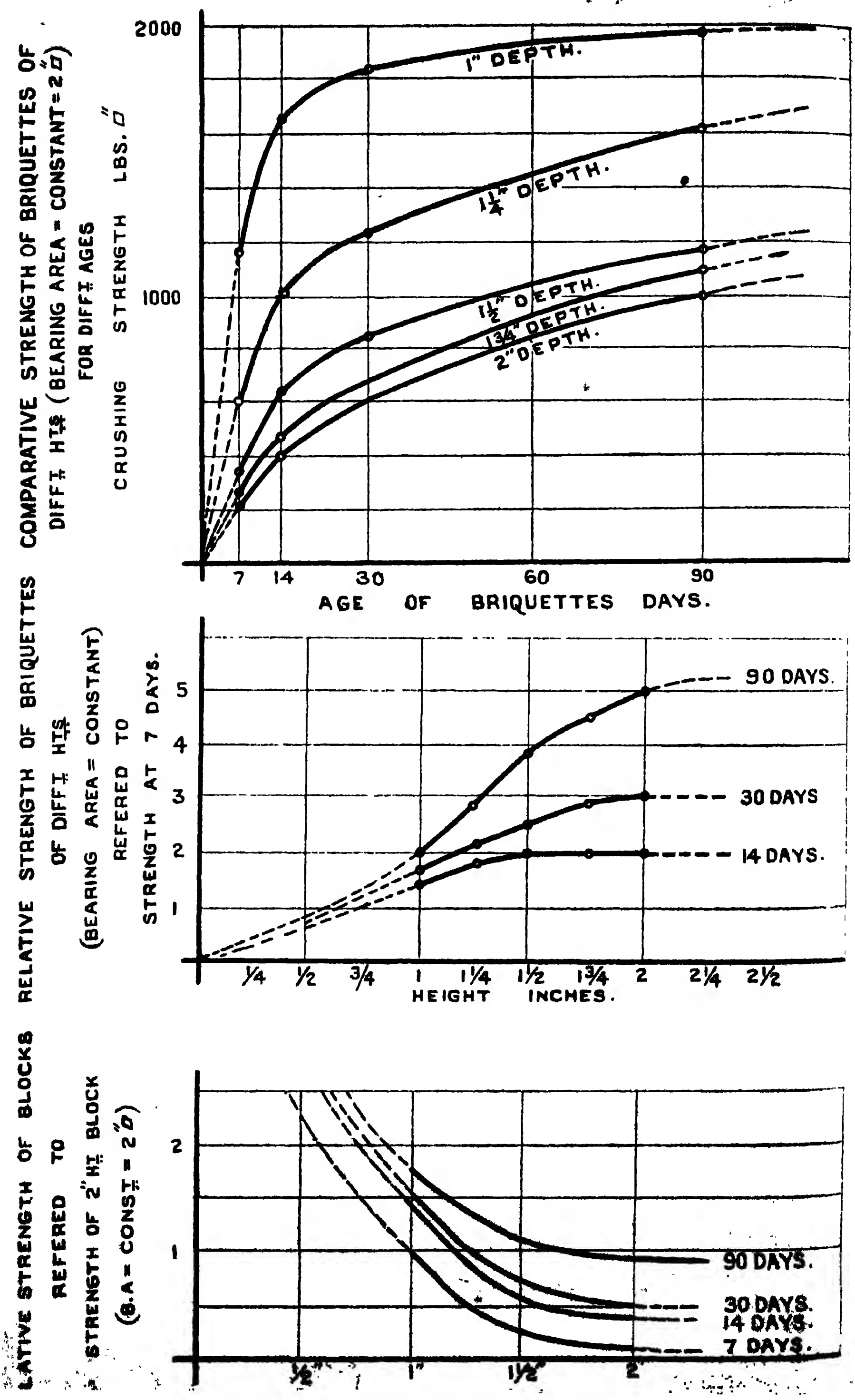
not convenient for moulding in the moulds usually used for tensile tests.

I agree with the remarks of Mr. Natesa Aiyar to the effect that it is necessary, and, in fact, an important duty of the Institution, to bring about standardization of the procedure adopted in testing the materials used in Engineering construction. His suggestion to test mortar under various conditions and in different methods can be carried out only by a fully equipped laboratory. The results of such tests may lead to a better and more definite understanding of the actual stresses involved in Dams and bring about suitable changes in the design and construction of such structures.

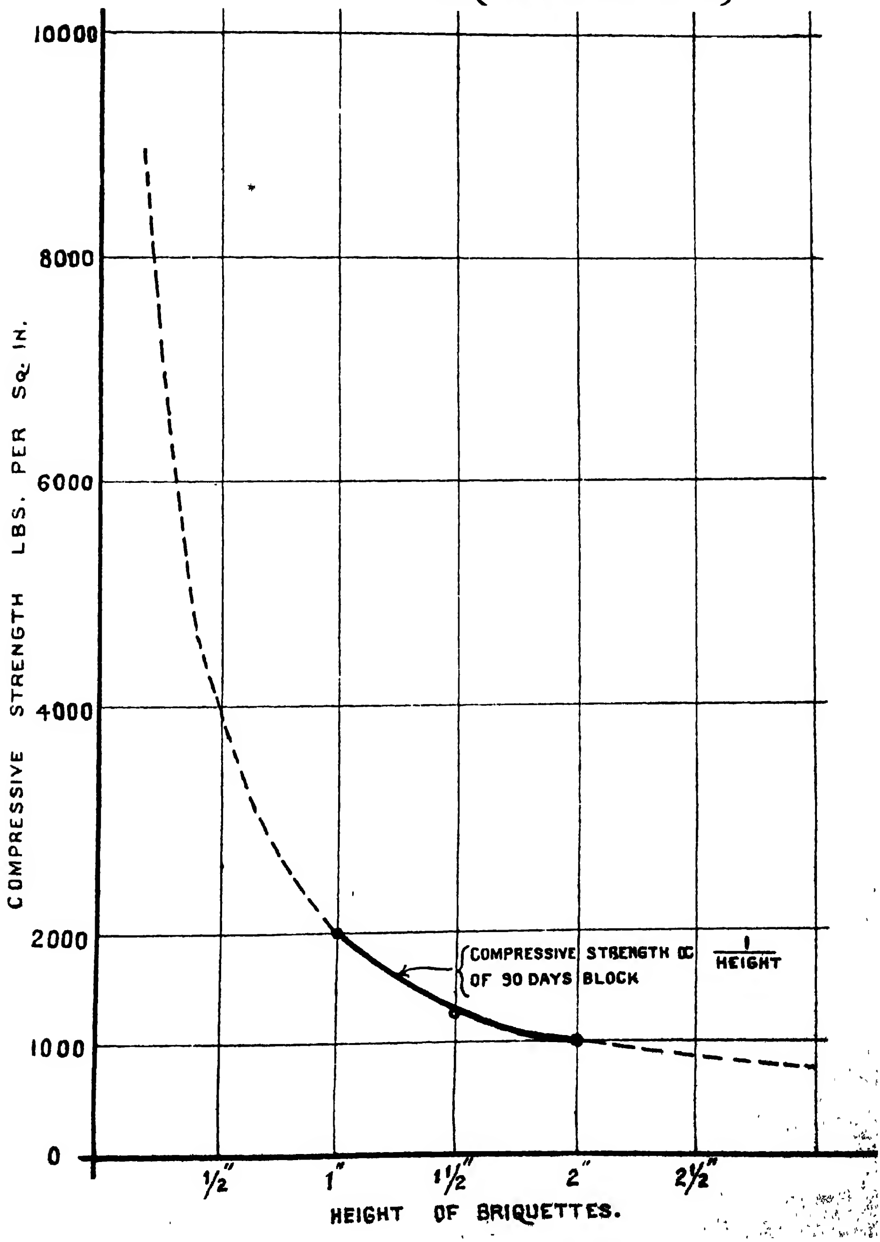
The author does not share the pessimism of Mr. Natesa Aiyar regarding the utility of the usual compressive tests of mortar in briquette form. These tests indicate sufficiently the relative strengths and merits of mortars for use in compression and form, at present, the most valuable guide, if not the only guide excepting the tensile tests preferred by some engineers, to decide the proportions and quality of ingredients to be used in any mortar required to act under a particular stress. Briquettes made from mortar cut out of portions of masonry on the Dam on which the Author is at present engaged have shown practically the same crushing strength as the usual daily test briquettes made in the laboratory and of the same age.

With regard to his remark about the applicability of the methods of tests described in the paper to hydraulic lime mortars only and not to fat lime mortars, it is desired to point out that it is so indicated in the introduction to the paper.

KRISHNAMURTHY ON MORTAR TESTING.



COMPARATIVE STRENGTH OF BRIQUETTES
OF DIFFERENT HTS (B-A= CONSTANT=2 ″□)



THE JOURNAL

OF

The Institution of Engineers (India)

INCORPORATED 1920

Edited and Published for the Institution by the Secretary,

8, Esplanade Row, East, Calcutta.

Vol. VIII. APRIL. 1929.

CONTENTS.

THE EIGHTH ANNUAL GENERAL MEETING.

The Eighth Annual General Meeting of the Institution was held in the Registered Office of the Institution, 8, Esplanade Row, East, Calcutta, at 11 a.m., on Monday, the 12th December, 1927.

PRESENT

Mr. R. D. T. Alexander (*in the Chair*)
,, J. S. Pitkeathly
,, H. Burkinshaw
,, C. Addams Williams
,, G. Bransby Williams
,, J. McGlashan
,, E. J. B. Greenwood
,, K. M. Kirkhope
,, A. H. Johnstone
Dr. A. Jardine
Mr. T. H. Richardson
,, P. N. Banerjee
45 Corporate Members and Mr. S. K. Banerjee acted as Secretary.

PROCEEDINGS

Mr. R. D. T. Alexander took the Chair at 11 A.M.

The Secretary read the Notice convening the Meeting

The Minutes of the Seventh Annual General Meeting were read and confirmed.

Item 1.—The Annual R[illegible] the Council and the Statement of Accounts [illegible]ied by the Auditors were handed to all Me[illegible]present.

[illegible]was propo[illegible] Mr. Ram Kishan that the Annual [illegible]port [illegible] Council and Audited Accounts be [illegible]opted.

[illegible] by Mr. C. Addams Williams and [illegible]mously.

Item 2.—It was proposed by Mr. S. N. Ghose that Messrs. Price, Waterhouse, Peat & Co. be re-elected Auditors at a remuneration of Rs. 350 per audit.

This was seconded by Mr. H. H. Reynolds and carried unanimously.

Item 3.—The Chairman announced at the Meeting that certain alterations were carried out in the By-Laws of the Institution and that these alterations were duly published in the Bulletins of the Institution for the information of Members.

Item 4.—The Chairman announced that the following Members had been elected by the Local Associations to fill the vacancies on the Council:—

Mr. C. Addams Williams
,, G. Bransby Williams
,, D. H. Remfry
Col. H. Cartwright Reid
Mr. A. F. Harvey
Lt.-Genl. Sir E. H. De Vere Atkinson
Rai Bahadur B. P. Varma

Item 5.—The Chairman reported

(1) that the Council had unanimously elected Mr. J. S. Pitkeathly as President of the Institution of Engineers (India), for the year 1927-28.

(2) that under Article [illegible] the following Chairmen of Local Associations [illegible] Vice-Presidents of the Institution:—

Bengal	...	Mr. R. D. T. Alexander
North-West India		,, D. G. Harris.
The United Provinces	...	Lala Jwala Prasad.
South India	...	Col. H[illegible].
Bombay	...	Mr. N. [illegible].

(3) that the four past Presidents[illegible]

Sir Clement Hindl[illegible]
Mr. H. Burkinsha[illegible]
Dewan Bahadur A. [illegible]ar.
Mr. W. H. Neilson, [illegible]

Item 6.—The Chairman then a[illegible] Chair, and read his [illegible]

Item 7.—The President then read his [illegible]

ANNUAL REPORT OF THE COUNCIL

For the Year Ending 31st August, 1927.

The Council have pleasure in presenting to the Members at the Eighth Annual General Meeting their Report of the progress and work of the Institution during the year ended 31st August, 1927.

MEMBERSHIP.

The changes in the Membership between the 31st August, 1926 and 31st August, 1927, are shown in the following table :—

	Honorary Members	Hon. Life Members	Life Members	Members	Life Assoc Members	Associate Members	Associates	Students	Subscribers	TOTALS.
Membership on 31st August, 1926 ...	3	2	41	312	4	473	4	122	21	982
Addition to 31st August, 1927	..		...		...		...	.	.	..
Elected	2		.	12	..	35	1	44	...	..
Transferred ...		.	5	9	...	5	...	...		113
Less Deductions :—										
Transferred ...	...			5	...	9		5		
Deceased ...	...		3	6	..	1		2	..	
Resigned ...	...	...	..	6	.	6	.	6		...
Struck off ...	...	..	...	4	.	10		15	.	78
Membership on 31st August, 1927 ...	[illegible]	[illegible]	43	312	4	487	5	138	21	1017

[illegible]OUNCIL.

Dur[illegible]view certain alterations took place in the Counc[illegible]bbs resigned from the Council on proceeding on leave. [illegible]E. J. B. Greenwood was appointed to the

Examinations Committee; Mr. R. D. T. Alexander and Dr. A. Jardine to the Administrative and Finance Committees; Dr. Jardine was also appointed to the Applications Committee.

Mr. J. W. Meares continued to act as the representative of the Council in England.

The Council regret to report the deaths of Sir Ganga Ram who had been a Member of Council since 1920 and of Rao Bahadur S. V. Rajadhyaksha who had been a Member of Council since 1923.

STANDARD SPECIFICATIONS.

The Council have continued to act as the Indian Committee of the British Engineering Standards Association and during the year received a considerable number of Specifications.

INTERNATIONAL ELECTRO TECHNICAL COMMISSION.

The Council have continued to act as the Indian Committee of the International Electro-Technical Commission.

JOURNAL.

Owing to the unfortunate illness of the Secretary, Volume VII of the Journal has not been published.

BULLETINS.

Bulletins Nos. 14, 15, 16 and 17 were published and issued to Members during the year. The Bulletins contained information concerning the work and activities of the Institution.

ISSUE OF PAPERS.

During the year the following Papers were issued to all Members of the Institution and were read at Meetings of the Institution.

"THE RAILLESS OR TRACKLESS TROLLEY SYSTEM" by Mr. A. Lennox Stanton (Member).

"MORTAR TESTING" by Mr. [redacted]rishnamurthy, [redacted]ciate Member).

"MAIN FEATURES OF THE COMPLETION WORKS FOR [redacted] WATER SUPPLY OF BOMBA[redacted]T. Prokofieff, (Associate Member).

EXAMINATIONS.

A list has been prepared of the Examinations which have been recognised by the Council as exempting from Parts A and B of the Associate Membership Examination, and this list was published in Quarterly Bulletin No. 16 for the information of Members.

AWARD OF PRIZES.

H. E. The Viceroy's Prize for 1925-26 was awarded to Mr. J McGlashan, Chief Engineer, Port Commissioners, Calcutta, for his Paper "NEW 80 ft. LOCK ENTRANCE INTO THE KIDDERPORE DOCKS". The prize for the year 1926-27 has not yet been awarded but is under the consideration of the Council.

Because no suitable Paper was submitted, no award of the prize of £20, offered annually by the Institution of Electrical Engineers was made.

ALTERATIONS TO THE BY LAWS.

Various additions and alterations were made in the By laws of the Institution to meet the requirements due to the progress being made by the Institution.

LOCAL ASSOCIATIONS.

On the 25th March, 1927, a new Association named "THE NORTH WEST INDIA ASSOCIATION" was inaugurated. The boundaries of the four existing Local Associations were also extended and the whole of India with the exception of Burma is now covered by Local Associations.

Membership of the Bombay Association increased considerably and the Association opened a Reading Room and a Library.

The Bengal Association also opened a Lecture Hall, a Reading Room and a Library.

As a result of the expansion of the Local Associations, the election of Members to the Council is now carried out in accordance with Article 9 as contemplated in Article 34.

[illegible]ACCOUNTS.

The audited acco[illegible]or the year ending 31st August, 1927, are appended. Th[illegible]ts show a deficit of Rs. 7,122-0-1 on the year's worki[illegible]

The Co[illegible]t after taking into consideration the increased activities [illegible] the Institution, the general position is satisfactory.

The Institution of Engineers (India).

Balance Sheet as at 31st August, 1927.

LIABILITIES & SUNDRY CREDIT BALANCES.

	Rs.	A.	P.	Rs.	A.	P.
CAPITAL—						
Permanent Reserve Account						
Entrance Fees	70,602	5	9			
Composition Fees (for Life Membership) ...	12,305	0	0			
Transfer Fees	1,345	0	0			
Donation	62,229	10	0			
				1,46,481	15	9
SUBSCRIPTIONS IN ADVANCE				1,137	12	2
SUSPENSE				930	8	0
LIABILITIES—						
For Expenses	2,318	5	2			
Bombay Association ...	1,332	4	0			
U. P. ,, ...	1.891	8	0			
S. I ..	901	8	0			
S[illegible] ...	1,442	13	6			
				7,886	6	8
B. [illegible]LOWANCE FUND				2,160	5	3
NA[illegible]LECTRO-TECHNICA[illegible]TTEE FOR INDIA				113	7	8
VIC[illegible]RIZE				500	0	0
IMPE[illegible] BANK OF INDIA (SEC[illegible]D)				6,476	13	6
Rs.				1,65,687	5	0

ASSETS & SUNDRY DEBIT BALANCES.

	Rs.	A.	P.	Rs.	A.	P.
FURNITURE & FITTINGS—						
As per last account ...	8,582	12	0			
Additions during the year ..	586	11	0	9,169	7	0
OUTSTANDING SUBSCRIPTIONS ..				4,298	0	11
SUNDRY DEBTORS				3,221	15	8
DEPOSIT				25	0	0
ADVANCE...				2,163	7	3
STOCK (Stationery & Diploma Papers)...				1,326	13	4
INVESTMENTS (Below market value)—						
6% 10 years Bonds 1930 ..	5,000	0	0			
Ditto 1931 ...	42,500	0	0			
Ditto 1932 .	16,000	0	0	63,500	0	0
ALLIANCE BANK OF SIMLA LTD. (in Liqn.)—						
On Permanent Reserve A/c ...	5.351	15	0			
On Donations A/c	11,771	1	1			
On Suspense A/c	5,298	1	4			
	22,421	1	5			
Less— Recovered.. ...	14.013	0	8	8.408	0	9
CASH—						
IMPERIAL BANK OF INDIA on Permanent Reserve A/c...	350	11	9			
In hand	305	11	6	656	7	3
INCOME & EXPENDITURE A/c						
Balance as per last A/c ...	65,796	0	9			
Add—Deficit for the year ...	7,122	0	1	72,918	0	10
			Rs.	1,65,689	5	0

We have audited the above Balance Sheet with the Books of the Institution of Engineers (India), and have obtained all the information and explanations we have required. No depreciation on Furniture has been provided for since 1925. Subject to this remark in our opinion such Balance Sheet is properly drawn up and exhibits a true and correct view of the Institution's affairs according to the best of our information and explanations given to us and as shewn by the Books of the Institution.

CALCUTTA:
5th November 1927

Sd. PRICE, WATERHOUSE, PEAT & Co., *Chartered Accountants* } *Auditors.*

The Institution of Engineers (India).

Income and Expenditure Account for the Year Ending 31st August, 1927.

EXPENDITURE.

	Rs.	As.	P.
To Sa[redacted] Wages	32,441	2	9
,, P[redacted]	784	15	6
,, Te[redacted]	28	2	0
,, P[redacted]ng	1,157	0	0
,, Stationery	1,275	14	10
,, Travelling	3,823	0	0
,, Conveyances	52	13	6
,, Rent	2,460	0	0
,, Lighting and Fans	85	14	3
,, Law Charges	286	14	0
,, Bulletins	1,410	0	8
,, Annual General Meeting	2,336	15	0
,, Diplomas	84	11	6
,, Subsidy to Local Associations	6,749	8	0
,, Audit Fee	350	0	0
,, Charges General	908	6	1
,, Bad Debts	1,671	8	0
,, Issue of Papers	850	5	9
Rs.	56,757	3	10

INCOME.

	Rs.	As.	P.
By Subscriptions	45,069	0	0
,, Interest	3,752	12	5
,, Sale of Standard Specifications ..	743	7	4
,, Sale of Publications..	70	0	0
,, Balance being deficit transferred to Balance Sheet	7,122	0	1
Rs.	56,757	3	10

PRESIDENTIAL ADDRESS

BY

J. S. PITKEATHLY, *C.I.E., C.B.E., C.V.O., D.S.O.*

PRESIDENT, 1927-28.

It is my great privilege to address you as your President for the coming year, and my first duty must be to express my thanks to the Council and members of the Institution for the great honour they have conferred upon me in electing me to this high office. I confess that I take upon myself the duties of this office with some hesitation and doubt whether I can properly fill the position; but one thought comes to comfort me. One of the philosophers said "The future does not come from before to meet us, but comes streaming up from behind over our heads." We, therefore, are not responsible to the present generation but to the future. The success of this presidential year—and we all hope that it be a successful year—will not be upon my shoulders but upon the broad and capable ones of my distinguished predecessors to whose ungrudging labours the Institution, in a very large measure, owes its position to-day; but on me devolves the duty of doing the utmost of which I am capable to consolidate and extend the work of my predecessors and to advance, in every possible way, the interests of this Institution, to which we are all proud to belong. A distinguished past President of the Institution of Electrical Engineers in one of his addresses likened the position of the President of an Institution such as ours to a spear point or the tool face, and very rightly stated that what may be accomplished by the point depends largely on the body behind it. I know your President is always assured of an overflowing measure of support and sympathy from your Council; but, if the good progress made in the past is to be maintained during the coming year, it is essential that the keen interest and support of every member of the Institution should be behind the Council in their labours on your behalf.

The aims and objects, for which this Institution was founded, are set forth in the Memorandum of Association, and are well known to you all. The Institution continues to make good progress, the total membership to-day being [illegible] the nett increase during the past twelve months 51. The conditions of and qualifications for membership are not being relaxed in any way, but are

rather being made more severe. Membership of the Institution is becoming more and more recognised as a qualification and as the hall mark of the Engineer.

The local associations of Bengal, Bombay, South India and the United Provinces continue to thrive, and during the past year the North West India Association was inaugurated.

Much has been accomplished since the Institution was incorporated in 1920 but much yet remains to be done before the ideals, which inspired the founders, are fully realized; and I want to see and do not hesitate to call for ungrudging service to the Institution from all its Members. I am certain that, if each member will actively realize that the Institution is *his* Institution, its powers of and opportunities for useful service to the Engineering Profession and to the people of this great country will be greatly enlarged. We, members of the Engineering Profession, are justly proud of our splendid tradition of service rendered in many cases regardless of the cost to the server, and I ask that every member of the Institution should to-day put to himself the question "What service can I render to the Institution during the coming year?" In order to help you to answer this question, I propose briefly to indicate the directions in which your assistance is needed, and I feel assured that my appeal to the members of the Institution for help will meet with whole hearted response.

Each member can help the Institution by bringing its aims and objects prominently before those members of the Engineering profession in India who have not yet felt it to be their duty to join the Institution. As I have already stated, the membership of the Institution now stands at 1,033. This is not unsatisfactory; but there is room in the Institution for many more. I know that there are many Engineers fully qualified for membership whose presence amongst us would add greatly to our strength, but who, for one reason or another, have so far refrained from joining and helping us in our work on behalf of the Engineering Profession in India. By inducing them to do so there is an opportunity to serve the Institution, and I ask each member to appoint himself a missionary on behalf of the Institution, and in season and out of season bring its aims and objects prominently before those engineers of his acquaintance whose help and support we are not at present able to enlist. I am sure that if an intensive effort is made during the coming year, our membership can be very substantially increased and the opportunities for good work which the Institution possesses can be still further enlarged.

You will note from the clause 3 c of the Memorandum of Association that one of the objects for which the Institution has

been established is "to diffuse among its members information on all matters affecting Engineering, and to encourage, assist and extend knowledge and information connected therewith by establishment and promotion of lectures, discussion or correspondence." Now, the records in the Journal of this Institution show that since its formation, a number of valuable and interesting papers on matters connected with Engineering have been submitted by members of the Institution and discussed either at the meetings of the local association or the parent body; but it is a matter of great regret to your Council and myself that no papers are available for discussion at this meeting. If the Institution is to fulfil one of the most important objects for which it was founded, members must bestir themselves and, even at the sacrifice of some of their leisure time, undertake the preparation of papers dealing with engineering matters with which they are most conversant. I am aware that, as a class, the members of the Engineering Profession are usually unduly modest, and many feel that the works executed by them are not of sufficient importance to be worthy of a paper; others may feel that the difficulties encountered by them in carrying out works were capable of very simple solutions when carefully examined, and the matter is not of a sufficient importance to justify the preparation of a paper for the Institution. But here I think they make a mistake. It is only by explaining the difficulties which we have met and the methods adopted to surmount them that we can hope to pass on our experience to others and so fulfil one of the main objects for which the Institution was founded. There is no country in the world with a larger variety of engineering work in progress than India, and many engineering problems and difficulties have constantly to be surmounted; and I appeal to all members, who may be in a position to help, not to allow a little trouble or sacrifice of time to stand in the way of this most important service to the Institution. If members shirk this service and a steady flow of suitable papers dealing with matters of professional interest is not maintained, then the usefulness of the Institution will be grievously impaired, as it will fail to serve one of the principal objects for which it was founded; but I have no fear that this will be the case, as I am confident that my appeal will not go unheeded.

I have briefly indicated above two directions in which each member may serve the Institution; but there is another direction in which even greater opportunities exist [illegible] service to the Institution and our profession. Sir Clement H[illegible] referred to it in his presidential address in 1922, and I feel I need make no apology for quoting the words used by him on tha[illegible] He said, "A very great responsibility lies on every Engineer who is entrusted with the practical training of the students or apprentices. It is

here that his opportunity for service to the Institution and the profession lies, and it is here that the greatest necessity exists for a realisation of those ideals of which I have been speaking." These are wise and weighty words, and I sometimes wonder if we fully realise our responsibilities to the rising generation and if each one of us is doing his utmost to discharge these responsibilities to the best of his abilities. In the course of time the students of to-day will be called upon to take the reins from the hands of those who now occupy the premier positions and if young men are to carry on the traditions and maintain the high standard of our profession, it is essential they should receive all the guidance, sympathy and support that may be necessary for their welfare and advancement. In this matter of vital importance the work is one which, to a great extent, must be left in the hands of individual members. I know that many members of the Institution have given unsparingly of their time and interest to this work, but lest any of our members have overlooked their obligations to the Institution and the young engineers with whom they are brought into contact, I commend to their notice the great opportunity which this work offers of rendering useful and lasting service to our Profession.

At the risk of incurring the criticism of making an unsuccessful attempt to preach a sermon instead of delivering a Presidential Address, I propose to take this opportunity to address a few words to the students and younger members of the Institution. It was my privilege some years ago to read two addresses, one delivered by Mr. C. H. Wordingham to the London Students' Section of the Institution of Electrical Engineers, and another by Dr. E. H. Griffiths, F.R.S., to the South Wales Institute of Engineers. These addresses made such a deep and lasting impression on me that I feel I can render no better service to the young men of our profession to-day than to tell them some of the things the lecturers said. Speaking to the students Mr. Wordingham said:—

"Most of you are starting, or have just started, on your careers: what is necessary for your success? Naturally you must be equipped with the very best scientific and technical education you can obtain. Subject possibly to the exception of a few brilliant men with inborn genius who do arise from time to time, the day has gone by when the man who picked up his knowledge as he went along can hope to attain a good position as an engineer. Every young man entering the profession must make himself acquainted with the present state of knowledge in the various branches, and must have a special knowledge of the one in which he proposes to practise. This knowledge, however, is only his bag of tools. The finest kit in the world will not carry him far if he does not know how to use them. It is in the use of them that the human element

comes in and that the exercise is called for of such abstract qualities as sympathy, kindliness, consideration, firmness, fairness and honour. These are the determining factors. The works manager who has favourites, who tries to get the better of his men, who bullies and insults those under him, or truckles to a dishonest employer by allowing scamped work, will never be a success. The adviser whose advice is coloured by his own self interest, or who is open to improper influences, may make money, but he will never attain an honourable position. The staff man whose heart is in his amusements and who only does so much work as he is compelled, doing it as an uncongenial task to be put out of mind when he puts on his hat, will find his promotion slow and his change of employment frequent.

"It is the man himself who counts. He must have his equipment of knowledge and skill, but also he must be able to use that equipment.

"Just one word on the subject of work. The fashion of the day is to exalt amusement as the chief aim in life, and to represent work as a task to be reduced to the shortest period possible. So far have things gone that a man's opportunity to work is in certain directions forcibly limited by Act of Parliament. Work is essential to our existence, and it behoves each one of us to find out for himself what kind of work he is best suited to perform and then to find means to make it his vocation. Ordinarily, many drift into their life's work, but I imagine that few drift into engineering: most enter the profession from deliberate choice, presumably because it attracts them. Fortunate indeed are they if they have correctly gauged their inclination, for the true engineer needs no artificial amusement, his work is his hobby and is seldom out of his mind, even when taking, as he should, legitimate relaxation.

"Most of us must have asked ourselves at one time or another: What is man's ultimate destiny? What are we here for? Each must find his own answer. I suggest that one of the most important objects in life is the formation of character, and if this be so, every thought, every action has its effect, indelible and permanent. Every job carried out then assumes an importance far greater than its intrinsic worth would give it. The primary thought in every engineer's mind should be: 'Will this thing which I am carrying out be to my credit as an engineer or to my discredit? Suppose the work which I am doing to day, and which will soon be out of sight, is unearthed 20 years hence, will its discoverer say of it that the job was well done or scamped?' I know of no pleasanter sensation than that of revisiting something carried out years ago and being able to

tell oneself that it has stood the test of time and is still functioning well. I would say to each of you: 'Try to do every piece of work primarily for the work's own sake and for the sake of its effect on your own character. The pecuniary reward in any one instance may be small or great, but in the long run that too will be added to you.' . . . . . A duty accomplished, a difficulty successfully overcome, a job well done, these are the things which confer real happiness, happiness worthy of man with his infinite possibilities and responsibilities."

Dr. Griffiths ended an address on the subject: "A closer union between pure and applied science" with these words:—

"There is no branch of natural science which the engineer can afford to ignore. His dependence on the physicist, the chemist, and the geologist is obvious, but I ask you to remember that the successful construction of the Panama Canal was due to the researches of zoologists, and even the designers of our aeroplanes had to call on the botanists for advice in the selection of their wing materials.

"The increasing complexity of the problems by which we are confronted—or rather our increased knowledge of their complexity—has led to the division of science into separate compartments, a separation which was inevitable although in some respects regrettable. Nevertheless we must remember that they are all parts of one organic whole. The laws of conservation and dissipation of energy, for example, are not bounded in their application by the walls of a physical laboratory. No worker in any one such compartment can afford to be ignorant of discoveries made in others, and more especially is this true of the engineer. It appears to me that one of our difficulties is the tendency to over-specialisation. The engineer should have easy access to all chambers in the temple of science.

"It is true that the views I have expressed may be regarded as Utopian, or, if you prefer it, optimistic and imaginative. I am unrepentant! I want to induce our young engineers to be both optimistic and imaginative.

"I delight in the following quotation from an address given to the Royal Society by Sir Benjamin Brodie in 1859: 'Physical investigation more than anything besides helps to teach us the actual value and right use of imagination—that wonderful faculty, which, left to ramble uncontrolled, leads us to stray in the wilderness of perplexity and error, a land of mists and shadows, which, properly controlled by experience and reflection, becomes the noblest attribute of man, the source of poetic genius, the instrument of discovery in science, without the aid of which Newton

would never have invented fluxions, nor Davy have decomposed the earth's alkalies, nor Columbus have found a New Continent.'

"I venture to repeat, at the risk of being thought wearisome, that the mental attitude of our young engineers towards the revelations of pure science should not be 'What possible use can there be in this discovery?' but rather 'What is the way in which this discovery can be utilised?' I would urge you in your leisure hours—and I admit they may be few—to study the works of the pioneers in pure science, and as you do so give free play to your imagination, always bearing in mind the words of Sir Benjamin Brodie: 'Imagination properly controlled by experience and reflection.' Waste not your efforts in vain pursuit of impossibilities, such as the squaring of the circle and perpetual motion; but build on the firm foundations laid for you by the masters of research, and strive to apply the principles they have established to the benefit and advancement of mankind.

"Determine that you will become liaison officers between the allied armies of pure and applied science. To the man of science, discoveries are an end in themselves; by the engineer they should be regarded as foundations on which he may surely build for the edification of mankind.

"I will close with the words, better than I could frame: 'There are three voices of Nature. She joins hands with us and says, Struggle, Endeavour. She comes close to us; we can hear her heart beating. She says, Wonder, Enjoy, Revere. She whispers secrets to us. We cannot always catch her words. She says, Search, Inquire. These, then, are the three voices of Nature, appealing to Hand, and Heart, and Head, to the Trinity of our Being.' "

No better advice has ever been given to young men starting their careers in the Engineering Profession than that contained in these quotations, and I hope that the students and younger Members of the Institution will find in these words inspiration and incentive to selfless service. Your profession has pre-eminently a boundless scope for service. The vastness of its domains and the strength of its influences provide inspiration to endeavour which, I feel sure, will sustain you when travelling the road which lies before you. I ask you to regard the Institution as an embodiment of the principles so well expressed by the distinguished men whose words I have borrowed; and I can point you no higher aim than that the proper exercise of your profession and the right conduct of your lives should serve as a mirror reflecting those principles.

Now the proper exercise of your profession, and indeed of any profession, implies something more than just "pulling your weight." As engineers, you will understand that maximum effort can only be exerted if the individual forces act in unison. In other words, it enjoins unselfish team work. Success and honours will not come to all of you; nor would I have you measure merit solely by this standard. As your work draws to its end and as you retrace the difficulties of the way which you have traversed, you will come to pass judgment on yourselves; and, if you are able justly to conclude that, 'I have given freely and unselfishly to the team,' you can find no fairer capital to crown your life's work.

And now I shall end with an earnest appeal to you all that you should, at all times and in every way, apply the high principles and traditions of your profession so to help to direct the course of events that this great country shall go up, and not down, in the scale of humanity, and in its upward progress shall be an agent for the uplifting of mankind at large.

THE
EIGHTH ANNUAL DINNER.

The Eighth Annual Dinner of the Institution of Engineers (India) was held in Peliti's Restaurant, Calcutta, on Tuesday, December 13th, 1927.

Mr. J. S. Pitkeathly, Chief Controller of Stores, Indian Stores Department and President of the Institution, presided. His Excellency Sir Francis Stanley Jackson, the Governor of Bengal, was the principal guest. The other guests included Col. Commandant E. A. Tandy, Mr. J. A. L. Swan, Mr. N. Pearce, Mr. S. C. Stuart Williams, Mr. T. M. Ainscough and Rai Bahadur A. C. Banerjee.

His Excellency Sir Francis Stanley Jackson proposed the toast "The King Emperor."

The President in proposing the toast "Our Guests," said :—

Your Excellency and Gentlemen :—

It is my pleasant duty to propose the health of our Guests. I sincerely wish that this duty pleasant though it is had fallen on someone better able to discharge it than I am. I am aware that we members of the Engineering Profession look upon ourselves as a highly gifted people—in fact I know that we hold the belief that in our profession the "salt of the earth" is to be found in generous measure and of full savour, but I fear we must admit that, with a few exceptions, the gift of making after dinner speeches clothed in pleasing and appropriate language is one which has not been lavishly showered upon us. We are, if I may say so, more accustomed to express ourselves in "works" than in words. I know there are exceptions to this rule as there are to every rule, but your Chairman to-night is not one of the exceptions and I must ask you to pardon my shortcomings and inability to do full justice to the Toast which has been entrusted to my care.

Our Chief Guest this evening is His Excellency Sir Francis Stanley Jackson, Governor of Bengal. This is the first occasion that the Annual Meeting of the Institution has been held in this part of India since His Excellency assumed office and by accepting

our invitation and honouring us with his company this evening, he has taken the first possible opportunity to show his keen interest in the Institution and his sympathy with his objects and ideals. I am sure I voice the thoughts and feelings of everyone present when I say that we all deeply appreciate the great honour His Excellency has done us in coming this evening.

We have with us to-night Mr. Stuart Williams and Mr. J. A. L. Swan, representing two great activities, the Port Commissioners and the Improvement Trust, which have done so much to raise this City and Port to the proud positions they occupy to-day. We hope to have an opportunity of seeing for ourselves some of the magnificent engineering work which has been carried out at King George's Dock when we visit the site on the 11th. Colonel Tandy, Surveyor General, and Mr. Pearce, the Agent of the Eastern Bengal Railway, are old friends and we are very glad indeed to see that they have been able to be with us this evening. We give a cordial welcome to Rai Bahadur A. C. Banerjee, President of a sister Institution, the Mining and Geological Institute of India. I must now thank the representatives of the Press who have honoured us with their company this evening. I would like to take this opportunity to express the Institution's indebtedness to the Press for sympathy, assistance and help in the past and I would like to assure you that we shall do our utmost to retain your goodwill in the future.

To all other Guests whose names I have not mentioned we give a very hearty welcome and hope they will carry away with them pleasant recollection of the evening.

I am sure you all feel that I have said enough and are anxious that I should bring these remarks to a close, in order that you may hear what His Excellency has to say to us. We hope that he will have something to tell us about some of the important engineering developments which are in hand or under consideration in this part of the country, and I will now ask the Members of the Institution to rise and drink to the Health of our Guests coupled with the name of His Excellency Sir Francis Stanley Jackson, the Governor of Bengal.

His Excellency Sir Francis Stanley Jackson, in responding to the toast "Our Guests" said:—

Mr. President and gentlemen—I am very grateful for the privilege afforded to me of responding to the toast of "The Guests." This enables me to thank you on their behalf for your most generous hospitality and gives me an opportunity of welcoming so many eminent engineers of Calcutta. I must also

thank the President for his personal reference to myself and assure him of my interest in your Institution and my sympathy with its objects and ideals. I note that the objects of your Institution are "To promote and advance the science, practice and business of engineering in all its branches in India and elsewhere, and to diffuse amongst its members information on all matters affecting engineering." You are meeting in conference when your discussions have afforded an opportunity of giving and gaining information in connection with your profession, which, I have no doubt, will prove of great value to you all. It is only after nearly nine months' experience in Bengal that I am able to realize the extent to which we must depend upon the help of our engineers for the satisfactory administration of India. I did not appreciate properly the ramifications of the engineer. Roads and buildings, railways, irrigation and waterways, sanitation, all come within his sphere. We could not get far without him.

I think I am not putting it too high when I say that upon the advice and work of our engineers the health and prosperity of the country largely depend. At the the recent Medical Congress in this city it was definitely stated that the first necessity in any attempt to prevent the scourge of cholera is the supply of pure drinking water. This is a matter for the engineer. The prevention of the accumulation and the removal of foul water and garbage by surface drainage and sewerage are matters for the engineer in conjunction with the Local Health Departments. The production of schemes of irrigation to supply water to districts which are periodically short of rain, and for the drainage of inundated areas, are the work of engineers. In all these matters much depends upon the efficient manner in which the work is carried out and a special responsibility devolves upon the junior branches of the service, who find themselves in charge of detailed work. Slovenly or careless work in detail may spoil a large and expensive scheme and result in more harm being done than good. Every man in each branch of the service must appreciate that upon the way his particular job is carried out depends the success of the whole.

It is also necessary to watch carefully that works in construction may not become in some indirect way the cause of trouble. I can conceive that in the construction of a road or railway, it may be necessary to dig borrow pits, which fill with water and provide a breeding ground for mosquitos. This will spread malaria. It would appear that wherever possible water supply tanks should be made in combination with the road or railway schemes and schemes taken up together might prove to be mutually economical.

The engineer and his work conduce greatly to the prosperity of the country. Trade development needs roads, railways, docks, etc., and general good communications. Mechanical and electrical engineers provide the machinery, lighting and power—so, put together, health and prosperity depend much upon, and owe much to, the efforts and skill of engineers.

We have a number of engineering projects of vital importance to the health and prosperity of Bengal. At present actually in the course of construction there are the Kidderpore Docks, the Bally Bridge, the Damodar Canal and the improvement of roads. The schemes in prospect are the electrification of railways round Calcutta, and this might result in a central railway station for this city.

And last but not least a bridge across the Hooghly, connecting Calcutta with Howrah, of such a character as may be able to cope with the enormous traffic which grows yearly. I can hardly believe there is any engineer in India who, if asked for an opinion, can honestly state that the present bridge, or anything like it, is suitable either structurally or economically for the purpose for which it is required. A permanent and solid structure capable of carrying the burden it must bear, undisturbed by tide or traffic, can surely be the only one worthy of consideration or worthy of Calcutta.

I have wandered far from the toast, but I must claim that indulgence which is invariably accorded to the Governor after dinner. If I have been too long you must blame your generous hospitality. On behalf of your guests I tender you our heartfelt thanks for your generous hospitality to-night and on their behalf offer you their sincere good wishes for success of your conference, your personal and professional prosperity.

Mr. S. C. Stuart Williams in proposing the toast "The Institution of Engineers (India)" said:—

Mr. President, Your Excellency and Gentlemen, I rise with pleasure to propose the Toast of "The Institution of Engineers (India)." I feel greatly honoured by being accorded this privilege for two reasons. One is that I am well aware my selection for this pleasurable duty is due chiefly to the fact that I am and have been for many years associated with undertakings, in whose operations the work of the engineer plays a most important part, and that it is therefore an indirect compliment to my brother officers who are engineers. In my long association with them I have learnt to recognise not merely their technical ability but their ingenuity and their loyalty to one another. I have learnt to admire the skill

and versatility which can be applied by an engineer when in a tight corner to that blessed word "Contingencies" and I have learnt with expectant admiration to recognise the unvarying certainty with which any departure from the path laid down by that narrow-minded man the Accountant, is always attributed in the last resort to an engineer who has either retired, or has gone to that final resting place where "the audit cease from worrying and the Chairmen grouse no more."

But in the second place, I am impressed by a realization of the intrinsic importance of this occasion, at which eminent members of your profession from the whole of India have honoured the city of Calcutta by their presence here to-night. When the subject of a Toast is an individual person, it is usual to speak of such a Toast as drinking to his health and I see no reason why we should not describe ourselves as drinking the health of the Institution, in the sense that we wish it a long and prosperous life, with constantly increasing numbers, a corresponding increase in its bank balance and reserve fund and most of all, in the amount and extent of its technical work and activities. Without going into any great amount of detail, I have found from the reports of the Institution for the last few years that its numbers have increased from 678 in 1923 to 736 in 1924, 929 in 1925, 982 in 1926 and that they now stand at the respectable total of 1033. These figures are sufficient to show that the Institution has passed beyond the stage of infancy to one of lusty youth, that it is growing in wisdom and stature year by year, and that it possesses every prospect of attaining a ripe old age in the generations that are to come.

To those of us who are accustomed to deal with figures—and I suppose that includes almost every one within this room—the question naturally arises what percentage do your Members represent of the total body of Engineers, Civil, Mechanical and Electrical within the sub continent of India. I am not going to attempt to answer that question for several reasons, of which I need only give you the last and most convincing namely, that I do not know the proper answer. But I think I am correct in believing that there are still a large number of Engineers at work in India who are eligible for membership but who have not as yet joined your Institution. One reason for this which has been suggested to me is that they are already members of the parent Institution in London and that they are quite content to rest their oars upon this qualification. With all respect to them, I suggest that it is possible to take another view of the matter. They might, I think, look beyond the present and they might also look beyond their own immediate and personal interest in the question. Beyond the

present, because one can only interpret the significance of to-day by reference to the history of yesterday and what so far as human foresight can judge, we believe to-morrow will bring forth. And I suggest to such that anyone who contemplates the great industrial and commercial future which must lie before India, by virtue of its very size and population and its natural resources, can entertain no doubt as to the countless possibilities of development in this great country. Assuming that it has already a large and prosperous net work of railways, there remains the fact that as judged by either area or population, the mileage of railways is far below the provision which exists in many other countries. Admit also that India possesses great and beneficent irrigation works, to which at present substantial additions are being made, it remains true that there is much still to be done by the irrigation engineer in a country the value of whose crops is Rs. 600 crores per annum. Turning to a still older medium of transport, the road-- we find it facing a new and greater future by reason of the development of motor transport. The possibilities of road development, accompanied of course by motor transport, are only beginning to be examined and if the Committee which is now at work is able to bring into being a body which will operate with the same efficiency as the Ministry of Transport does in England, we may look to enormous improvements both in the state of existing roads and in the construction of new feeder roads in every province of the country. With this road development, there will inevitably come *pari passu* the growth of a motor trade which will make our present motor trade, in itself no inconsiderable item, fade into insignificence. I am told that in the United States there is one car for every 6 inhabitants, and in India 1 for every 2,600- so that with the increasing wealth which we hope the future will bring to India, there is a large margin for expansion. Nor is the day far distant when we should see the beginnings of an indigenous motor industry. Add to such developments the potentialities of this country in the great manufacturing industries, when the achievements of science are wedded to the skill of Indian engineers and to enlarged financial resources,—the weaving of cotton goods of the finer qualities, the utilization of our natural resources in the chemical industries with their endless ramifications, the manufacture of glass and pottery and the possibilities of mining and smelting the non ferrous metals. I am not of course suggesting that such development is a matter of the near future and I admit that from some standpoints, one cannot regard altogether with equanimity the prospect of India changing over from being primarily an agricultural country to becoming one which is studded with factories and workshops. Personally, I hope that such development will be

of slow growth, because I should like to see it effected without recourse to the doubtful medium of 'protection.' But I have ventured to suggest these possibilities on the far horizon as showing the opportunities which I think will sooner or later come to members of your profession. And I suggest that those who launch such schemes will, inevitably, come to utilise more and more the Engineer and Scientist who has been bred and trained within this country. If that view be correct, it must follow that your Association will grow with corresponding speed and strength and that so far as Indian Engineering is concerned, it will at some date in the future become the dominant body of the profession.

I suggested also that this question should be looked at from a wider stand-point than that of the individual concerned. Those members of the British Associations who have hitherto stood aloof might ask themselves whether their obligations towards the country of their adoption and towards those who have worked in that country under their guidance and supervision does not render it incumbent upon them to do what lies in their power to assist the Indian aspirant towards hitiher efficiency and a wider sphere of usefulness. Holding as I do that the answer to this question must be in the affirmative—it is with pleasure that I extract from a recent report made to me by the engineer in direct charge of the King George's Dock where 14 Indian civil engineers are employed, the following:—"So far as possible, measures have been taken to give the Indian engineers opportunities to broaden their experience. Lectures and discussions have also been promoted, to enable them to grasp the underlying principles of the work and to expand their interest in sections of the work other than those on which they were engaged."

This brings me naturally to a difficult and somewhat contro versial subject but one which is present in the minds of most of us. that is to the insistent demands from young India for a larger share in the higher posts of administration, engineering and other professions. With that demand there is a great and growing sympathy but it is tempered, I think, in the minds of thinking men with certain qualifications. If there is at present a gap between these high posts and the Indian aspirants, that gap can be filled only in one of two ways, either by a lowering of the standard of efficiency and attainment or by an improvement in the level of those who aspire to the higher posts. The former alternative should I think—and I see other speakers have at other meetings expressed the same view—be definitely disowned both in the real interests of the aspirants themselves, and in the wider interest of the country. It is to the latter alternative, an improvement in educational and

technical equipment, in keenness, in initiative, in the habit of taking and bearing responsibility, by the Indian, and last but not least in the preservation of these qualities throughout a working life, to which we should nail our flag and to which we should stead fastly adhere.

I am aware that what I say will not satisfy everyone but I doubt whether some of those I have in mind would be satisfied with anything I might say. There are some who received the announcement of any further advance in the direction desired not merely with indifference but with active hostility. In fact, they remind one of the story of the little boy, who when asked whether he would like to see the little sister which the stork had brought him, replied, that he did not want to see the little sister, but he did want to see the stork.

May I conclude by quoting a passage which seems to me to suggest the highest ideal which any engineer can place before him. It is taken from a well-known book by a well-known American Railway Engineer, Wellington's Railroad Location. It is as follows:—"The desire to do good work for its own sake is then the only real guarantee that good work will be done; for although a kindly Providence has given the latent power to do bad work of this kind to every human being with a tolerably observant eye and intelligence enough to lay up bricks, most assuredly the power to do good work will not come by nature," and he concludes his chapter by himself making a quotation from another great American thinker, Emerson, which is, I think, also worthy of quotation: "Work is victory, wherever work is done, victory is obtained. There is no chance, and no blanks. You want but one verdict: if you have your own, you are secure of the rest."

If I felt any doubt about the reality of these sentiments it would be dispelled by one outstanding example of an eminent Indian business man and engineer who, aiming neither at money nor fame, has yet found both as well-earned rewards of the industry and integrity which he has placed foremost throughout his life—I mean the gentleman with whose name this Toast is associated—Sir Rajendra Nath Mookerjee.

Gentlemen, I ask you to rise and drink the Toast "The Institution of Engineers (India)."

Sir Rajendranath Mookerjee in responding to the toast "The Institution of Engineers (India)" said:—

Your Excellency Mr. President and Gentlemen, I rise to respond to the toast of the Institution of Engineers (India) which has been so eloquently proposed by my friend, Mr. Stuart Williams,

in such sympathetic and instructive terms, and honoured so enthusiastically by you all. Looking round the table I see signs of surprise in your faces as to why I should again come up before you to respond to this toast. I can assure you that I am not so ambitious, at my age, to force myself into this honour, but all other past Presidents excepting Mr. Burkinshaw are abroad at the moment and Mr. Burkinshaw has been commanded by his doctors not to strain his voice. Apart from the disadvantage to me, I am painfully conscious of the disappointment I will cause to you all. I have not been in close touch with the work of the Institution during the last two years owing to my varied public duties which necessitated my absence from Calcutta for a considerable time. Indeed, I feel myself to be a back number now, being the seniormost past President, having had the honour of being elected as President at the Inaugural Meeting of the Institution. Still I wish to express, however feeble my voice is, both in my personal capacity and on behalf of the Institution, our grateful thanks to Mr. Stuart Williams for his appreciation of the Institution's work and the kind and flattering words he has said about me only to make me blush before so many young men. Mr. Stuart Williams occupies an eminent position and his encouraging words will stimulate lively interest in the Institution's work.

Mr. Stuart Williams has, with some reason, twitted the Engineer for sheltering his estimates behind "contingencies." Perhaps he forgets for the moment that no administrative officer from the Chancellor of the Exchequer downwards, not even the Chairman of the Port Commissioners, can escape from the use of this very useful provision. The Engineer has some justification, for when he digs the ground he cannot know what difficulties each foot of the mother earth may bring forth and may upset his carefully worked estimates. The narrow-minded Accountant has also come in for Mr. Stuart Williams' banter, but here too I am afraid there is no escape. I have heard high officials of Government swearing at Accountant-Generals for disallowing travelling bills. But I am not sure whether such trifling items pertaining to the Chairmanship of the Port Trust are subject to audit; if not, I congratulate Mr. Stuart Williams on his exceptional luck.

I heartily endorse every word of Mr. Stuart Williams' speech wherein he makes a forcible appeal to engineers who are members of the parent Institution in London and have not joined our Institution. I hope his message will be read by all and carry conviction to their minds.

The wise and encouraging words, which Mr. Stuart Williams has said about Indianisation, are very welcome to us Indians. I

thank the Port Commissioners on the methods they have adopted to train the young Indian engineers. As an Indian, I have no hesitation in affirming that we appreciate the need of the development of those qualities on which Mr. Stuart Williams has laid emphasis but, provided skill and efficiency are equal, preference should be given to an engineer of Indian domicile in his own country.

It is essential that the status of the Institution should be clearly established and it was with this object that both at the Inaugural Meeting and on the occasion of the Fourth Annual Dinner I pleaded for directing our afforts towards raising a reserve fund of a lakh of rupees, having a home of our own and increasing our membership roll, conditions, which I was told in a casual conversation by the then Viceroy Lord Chelmsford and Sir Thomas Holland, might secure for the Institution a Royal Charter of Incorporation. I appeal to you again to strive to fulfil these conditions, for the Royal Charter means a recognised status which in turn will accelerate the pace of progress. As an earnest of this appeal I promise a contribution of Rs. 10,000, i.e. Rupees Five thousand each from the firms of Martin and Company and Burn and Company respectively, provided the Institution can raise an aggregate of Rupees Fifty thousand from other engineering firms of India.

In conclusion, Gentlemen, I thank you for the cordial manner in which you have received the toast of the Institution and for your good wishes for success which Mr. Stuart Williams eloquently conveyed in proposing the toast.

WATER SUPPLY BY DECENTRALIZED STORAGE.

BY

F. C. GRIFFIN, Member.

GENERAL.

Maintenance charges in connection with the municipal water supplies of Bengal are met principally from income obtained by the imposition of water rates. In many waterworks in different parts of the world, the income is obtained solely by charging for quantity consumed, as measured by meter. This is a satisfactory method, and has been applied in Bengal at Kalimpong (a non-municipal area) without any difficulties having arisen. It is however not applicable to the municipalities of Bengal, for the simple reason that the large majority of the people are too poor to be able to afford house connections. In order to give such people drinking water, street standposts have to be erected, from which they carry away water in their own vessels. Obviously it would be impossible to maintain the waterworks unless these people were called upon to pay something, and also it would be unfair to let them have water free of any charge while the few people who have house connections met the whole cost by their meter payments. Under such circumstances no one would take house connections. The imposition of water rate is therefore necessary, and this is based on the valuation of holdings, so that householders pay according to their means.

In addition to the street supply, however, householders who can afford it are allowed the privilege of a private house connection. They have to pay the whole cost of such connections, and in addition are generally called upon to pay a fee or "contribution" to the general waterworks funds. But in practice this has introduced a very serious difficulty. The householder who pays his water rate is under the impression that he can take as much water as will run out of his taps. He and his family do not trouble to turn off the taps, in fact he lets them get out of order,

and remain so, and great waste of water occurs. To combat this difficulty, a system of metering of house connections has been put into practice. The meters are supposed to be read regularly, and a charge made for excess consumption. According to a code of by-laws, a free allowance is settled for each house,—based on the amount of water rate paid,—and any water consumed beyond that allowance is to be paid for at a certain rate per 1,000 gallons. The intention of this arrangement is twofold, first, that the householder, knowing that his allowance is limited, will economize water so as to avoid the payments for excess consumption, second, that an additional source of income will be found in such excess consumption charges as are imposed.

In practice, however, the system has not worked well, and attention is drawn to the following statement, which shews the position with regard to metering in the principal waterworks of Bengal.

Name of Waterworks.	Number of			
	House connections.	Meters fixed.	Meters in order.	Meters read regularly.
1 Serampore	456	62	7	7
2. Hooghly-Chinsurah ..	700	696	447 Reported in order	Nil.
3. Uttarpara	118	115	106	115
4. Howrah	7077	1228	1132	1132
5. Burdwan	606	6	6	6
6. Midnapore	116	113	Not known	Nil.
7. Berhampore (under the control of Public Health Deptt., Bengal) ..	239	239	198	239
8. Krishnagar	156	156	154	156
9. Barisal	80	80	2	2
10. Darjeeling	529	183	175	183
11. Dacca	1730	589	180	180
12. Chittagong	540	432	379	379
13. Comilla	137	55	Not	read
14. Mymensingh ..	345	83	75 (275 meters	75 purchased)
15. Narayanganj ..	473	47	Not known	Nil.

With regard to this negligence in metering, a fact should be mentioned which applies to the older water-works. In the case of house connections which were given prior to 1916, the Municipality has not yet been given powers by which it can oblige the householder to meter his connection at his own expense. Meters could however be fixed at the expense of the Municipality A perusal of the statement leads one to the conclusion that the policy of charge by combined water rate and meter has not up to the present been successful in Bengal. The fact of the case is that metering is often looked upon with disfavour by municipal authorities, and when meters are fixed, they are often allowed to get out of order or are not read.

And for a full appreciation of the circumstances one must put oneself in the position of an average householder,—the man who pays his rates and who really wishes to avoid doing anything detrimental to the waterworks. He does not waste the water himself, and being away on business all day does not know what wasting is done by his family or servants. In fact he has no means of knowing whether " waste " has occurred,—*i.e.*, whether his free allowance is being exceeded, until some time after the end of the quarter, when he is suddenly faced with a bill. Being a man of moderate means, he naturally objects to pay this, especially as it is in the nature of a fine,—a payment for a thing not really received (actually the water ran away down the street drain!). He calls on his neighbour to ventilate his grievance, and finds him ready to lend a sympathetic ear, as he is in the same position. Others are brought into the discussion, and finally a plot is hatched whereby some method of evasion of payment for excess consumption is devised.

As will be seen later on, the system now suggested would put the householder in a very different position. On his return home from business, he will find out at once that waste of water has occurred. He will immediately discover the culprit and will suitably chastise him, and thereafter such waste of water will not occur again. He will himself look round his taps, and when he finds one requiring a new washer, will at once send for the plumber and have it put right.

In addition to the wilful and careless waste already mentioned, there are however forms of waste which are, to a certain extent, unavoidable in the present system of water supply. Owing to shortage of funds, it is impossible to construct waterworks of anything more than a very limited capacity for Bengal municipalities, and in order to ensure that everybody gets some amount of water, intermittent supply has to be resorted to. The

people of Bengal municipalities have grown accustomed to the idea of intermittent water supply, since they have never known a continuous one, and an intermittent supply is better than none at all. Such a form of supply however brings with it a train of evils, the chief of which is that waste of water is actually caused by it. For a householder, knowing that the supply will be avail able for only a short time, draws considerably more water than he wants at the moment, and stores it, generally in open vessels or tanks (*chowbatchas*). Only a part of the water is used, and the remainder lies in the open tank, exposed to any accidental pollution. When pressure comes on the mains again, the *chowbatcha* is first completely emptied, and is then refilled with fresh water. This is a practice which cannot be condemned, although it means great waste of water, for the water remaining in the open tank cannot be considered safe for drinking. The remedy for the wastage lies in the abolition of the *chowbatcha* and the substitution of a covered tank with locked lid, arranged so that pollution cannot take place. The amount of water wasted from a *chowbatcha* would in many cases be sufficient to supply an additional house connection, and the present waste of water in a few connections prevents the making of more connections which are urgently required.

The intermittency of household supply is in addition a source of annoyance and expense to the consumer, annoyance in that some times he happens to have no water stored, and on coming to the tap finds no water there either,– and expense in that he has to provide additional vessels for storage.

The following method of waterworks design will overcome the difficulties referred to above and will in most cases give a supply at reduced capital cost. The main point of difference from the present system is that the necessary storage will be decentralized; in other words, that small storage reservoirs on the roofs of houses and at the sides of roads will be substituted for the central reservoir.

In the present system, water is pumped from the source of supply at a constant speed into a central reservoir from which it gravitates to the consumer at a speed varying with the demand. Any excess demand beyond the pumping rate is made up by the water stored during the time when consumption is less than the pumping rate. The pipes of the distribution system are designed to supply the maximum demand, which may be anything from two to five times the average.

Theoretically this system of design is the best, and, in countries where the climate and the habits of the people do not conduce to excessive waste, it cannot be improved upon. It should be clearly understood that the author is not putting forward these suggestions as a general improvement on the existing system, but as a means of meeting the particular needs and conditions of Bengal. In Bengal, indeed in most parts of India, the climate is such that both rich and poor, European and Indian, tend to use water very extravagantly. In wealthy communities, the way to meet the situation is obvious, *viz.*, to supply abundant water. But the mufussil towns of Bengal are the reverse of wealthy communities, and yet the vital necessity remains,—that of providing a pure water supply. The quantity given must at least be sufficient to supply every one with water for drinking and cooking. Something must be done therefore to meet the requirements in such a manner that wastage will be prevented.

The author also wishes to make it clear that he does not claim that his proposals are all novel. Supply of water without central storage and direct into road side tanks has already been put into practice in a few towns of Bengal, and a number of schemes have been designed on this basis. In other water-supply schemes in different parts of the world house supply is being done from roof storage tanks. The present proposal is simply that the application of the system be extended and be made more practicable by means of a generally higher pressure of supply, and that the principles and rules under which house connections are given in Bengal should be changed.

DESIGN OF THE SYSTEM.

The general principle of the system is then that, in addition to street storage tanks, each house connected to the mains will have a storage tank on its roof, or in an upper storey at such a level that it will command all the taps required in the house. The connection from the street main to the tank will be controlled by "check pipes" (to be described later) so that only the quantity of water to which the householder is entitled will pass during the hours of pumping. The outlet from the tank will be a larger pipe connecting to as many taps as the householder desires. During the hours when the household demand is nil or very small, the water level in the tank will rise, and during the hours of heavy demand the water level will fall. In this system, economy in the use of water by the householder would be automatically obtained. If one person leaves the tap running or uses an unnecessary amount of water in his bath, the supply in the tank will be exhausted, and others will have to wait until it has had time to recuperate. The head of the house will see to it therefore

that such waste does not occur. The capacity of the storage tank should be of at least one day's consumption, so that as a rule the tank would not become empty except by excessive use of the water.

The engineering points involved in such a system will now be considered seriatim.

THE CENTRAL PUMPING STATION.

Pumping will have to be carried on for the same number of hours each day in spite of variations in the daily demand. There will also be variations in the demand during the day, owing to the closing of the ball valves in those tanks which have become full, or re-opening of the same. It follows therefore that a pumping installation must be installed capable of maintaining a constant head in spite of varying demand. With steam plant this is perfectly simple, as it can be worked at any speed. The speed of an oil engine however can only be varied by about 10 per cent while it is running, so that in oil driven plant, one of different alternatives must be adopted, some of which are:—

(*a*) The supply to be given by centrifugal pump. This form of pump will deliver a varying quantity of water at a practically constant head, and it is possible to run such a pump against the pressure in a closed main. If no water is being drawn off, the water will simply slip at the pump. This method is not however to be recommended, since the full horse power of the engine is being absorbed although no water may be delivered by the pump.

(*b*) Some form of variable speed gear may be inserted between the engine and the pump. In this line there are recent inventions, notably the "P. I. V." (Positively Infinitely Variable) gear, and the Keenok gear. The writer has not yet had an opportunity of testing either of these mechanisms, but he is confident that it is not beyond the power of the modern mechanical engineer to produce a really satisfactory infinitely variable speed gear, capable of transmitting such horse-powers as are generally required in waterworks pumping plant.

(*c*) The pumping capacity may be divided between smaller units, and the drive can be through a counter-shaft with fast and loose pulleys, so that one, two, or three pumps can be thrown in as required.

(*d*) In three-throw ram pumps, the pump may be designed so that either of the rams can be independently by-passed. This system, combined with the available variation in speed on the engine, would give the required variation in supply.

The man on duty in the pumping station would have to keep an eye on the pressure gauge, and vary the machinery as required in order to keep the pressure constant. A Bristol automatic pressure recorder would also be fixed in the pumping station, in order to check the work of the attendant and to maintain a record wherewith to combat complaints which might be received as to shortage of pressure.

In the case of pumping direct from a clear water reservoir or from a tube well, it would be advisable to insert a large air-vessel immediately after the pumps, or else a standpipe. When pumping direct through a pressure filtration plant, an elevated storage of a small quantity of wash water is required, and this elevated reservoir may be used as a pressure regulator. One method by which this can be done is shown in the diagram, Plate I.

HOURS OF PUMPING.

The pumping machinery, filtration plant (if any), and distribution system will of course be designed to supply in a certain number of hours the maximum daily quantity of water required. This number of hours varies according to circumstances, but is generally taken as eight,—the ordinary duration of one shift. For pumping station attendants however, this can be stretched to ten. The number of hours should be as long as possible, as thereby the capacities of pumping and filtration plants can be reduced and consequently a reduction in capital cost effected. The question as to whether a further reduction in capital cost is necessary at the expense of an increase in maintenance cost (by working two shifts) is a matter for consideration in each individual case. One point must however be made clear, *viz.*, that in this proposed system of supply, pumping will have to be carried on for the full number of hours per day right from the commencement of operation of the waterworks, since each house connection pipe will be regulated so that the required quantity of water passes in the fixed number of hours. This may be advanced as an argument against the proposed system, but it has not much force, since in most waterworks that have been started, a very considerable number of house connections have been made within a short time. and the full demand has soon come on to the system. So that the lack of economy caused by long hours of pumping in spite of small supply will be of short duration.

DISTRIBUTION SYSTEM

As has already been stated, in the usual method of waterworks design, the distribution system is arranged to deliver water

at a rate 2 to 5 times the average. In the proposed system the pipes can be designed to deliver at the average rate, since the storage is at the end of the mains instead of at the beginning. This means an economy in the pipes, but against the reduction in the size of pipes enabled thereby must be placed the need for an ample capacity so that the drop in pressure due to friction losses will be small. In order to maintain a constaint flow through a service pipe and give a fixed number of gallons per day to the house, it is necessary that a practically constant pressure shall be maintained on the street main from which the house connection is taken. In order to provide a distribution system economical in first cost, it is therefore proposed that the town should be divided into zones of supply. The pipes within each zone will be of ample size so that the drop in pressure in them is very small. Each zone will be fed at its centre by the trunk main from the pumps, and at that centre will be placed a pressure reducing valve. The function of the reducing valve is to give a constant pressure at its outlet in spite of a varying pressure at its inlet. The usual drop in pressure may therefore be allowed in the trunk main, and a constant pressure (which must be a little more than the height of the highest house to be supplied), will be maintained in the branch or zone mains. This method of distribution will also enable the decentralized system to be applied to towns in which there are differences of level, for the zones can be arranged in areas of about the same level, and constant pressures thus maintained.

Plate II shews a plan of a distribution system designed on these principles, while Plate III gives a longitudinal section shewing the hydraulic gradients. The example taken is that English Bazar, a town in the Malda district of North-West Bengal, having 15,000 inhabitants to be supplied with 100,000 gallons of water per day. The town naturally divides itself into six zones, and these can be fed by the pipe system shewn. It will be seen that near the pumping station there are no houses except three large ones, the Collector's and Police Superintendent's quarters, and the Dak Bungalow. It would be scarcely necessary to put in a separate zone and reducing valve for these three houses. They can be connected direct to the trunk main, and would in consequence have a larger number of check pipes. The pressure in the trunk main near the pumping station will be fairly constant and therefore the flow to the storage tanks of these houses will be sufficiently regular.

Plate III is a section on the longer of the two trunk mains, continuing through zone No. IV, and is self-explanatory.

SERVICE PIPES.

The function of the service pipe is to deliver water from the street main direct to the roof tank. It is to be regulated so that it will deliver not more than a certain number of gallons during the hours of pumping. That number of gallons will correspond to the amount of water rate paid by the householder, according to a fixed table of allowances. Rules will have to be formulated fixing the allowances and regulating the granting of house connections. A draft code of Rules is given in the appendix, and these will be further discussed later. For the present however it will be seen that a service pipe is to deliver a certain number of gallons at a uniform rate during the whole of the pumping hours. Its size can therefore be smaller than a service pipe under the present conditions of supply,—conditions under which the pipe is generally required to deliver nearly the whole of the daily supply in 2 or 3 hours. A $\frac{1}{2}''$ service pipe will be found sufficient in all ordinary cases and in many cases a $\frac{3}{8}''$ pipe will deliver all the water required. But the pipe must be provided with some means whereby the flow can be cut down to the rate at which only the required daily quantity passes. Obviously from the purely mechanical standpoint, the simplest thing would be to insert a tap, which can be regulated down until the required flow passes. But a tap, and even a locked tap, would afford too great a temptation, and could be too easily opened so as to allow more than the stipulated quantity of water to pass. To overcome this difficulty, the system of check pipes, shewn in Plate IV, is suggested. In this, the connection is coupled on to the main by means of an ordinary ferrule,—a stop ferrule would be unnecessary. A stop tap is required for completely shutting off the connection when necessary, and this should be placed in a surface box at the flank of the road. Next to the stop tap,—and accessible from the same surface box,—is a fitting containing a coarse strainer, the function of which is to catch any bits of scale or other solids which might choke the check pipes. Immediate following, and still in the public street, are the check pipes. These consist of $6''$ lengths of $\frac{1}{2}''$ pipe, with copper tubes inside them run in with pitch or lead, as shewn in figure 2 of Plate IV. The size of the copper tubes will be $\frac{1}{4}''$, $\frac{3}{16}''$, or $\frac{1}{8}''$, as required, and the number of check pipes to be put in series will be determined by experiment in each case. After the roof tank is fixed, and when pressure is on the main, it will be an easy matter to arrive by trial and error at the number of check pipes required. The rise of water in the tank can be measured for say half an hour, and from that the rate of flow can be seen. After the first few connections have been made, the fitters will be able to decide on the right number of check pipes

very quickly. Experiments have been made with a few check pipes, the results of which are given in the following table:—

Test.	Size of copper tube inside the ½" pipe.	Length and Particulars.	Discharge in gallons per hour under head of 5 ft.	10 ft.	15 ft.
1	1/4"	One length, 1'—0" long	54	78	102
2	,,	The same tube cut into two pieces and joined by two ½" sockets with ½" nipple between	48	72	90
3	,,	The same again, but joined by one ½" socket so that the space between the ends of the ¼" tubes was a little less than ½"	51	78	96
4	,,	Two 1'—0" lengths in series ..	30	42	60
5	,,	Three 1'—0" lengths in series ..	27	36	48
6	3/16"	One length 1'—0" long, with slight bends at the ends	34·5	49·5	60
7	1/8"	Two 1'—0" lengths in series ..	9·75	15	16·5

Test No. 2 in comparison with No. 1 is interesting as shewing the effect of making a break in the copper tube and introducing a little chamber between the two ends in which loss of head takes place by eddies. No. 3 test shows that the two ends of copper tube must be separated by a sufficient distance in order to allow such eddies to take full effect. Check pipes as shewn will be made quite cheaply. A good length of pipe would be run at one time, and would be subsequently cut up into 6″ lengths, the ends of which would then be threaded. The ends of the copper tubes must *not* of course be bell-mouthed.

It will be seen that the object of the substitution of check pipes for a partially closed tap is that, in this method of regulation, it will be a somewhat prolonged and difficult operation to make the alterations necessary to get more water, and that such alteration can only be made publicly and in broad daylight, and consequently with the consent of the municipal authority.

ROOF TANKS.

It is important that the roof tanks shall be installed in a proper manner. To drop a tank on a roof in the casual fashion

with which many of the roof tanks in Calcutta have been treated is not at all in conformity with the present proposals. Suggested arrangements for the roof tank are shewn in the drawing Plate V. Galvanized iron tanks will generally be used, but any householder who is willing to spend a little more money should be encouraged to put in a reinforced concrete tank. The capacity will be usually about a day's supply, but if a householder wishes to have more storage so that surplus water from one day may be used the next, there is no reason why he should not provide larger tanks. In a town in which filtered water is used for water closets, a house provided with sanitary fittings should have two separate storage tanks, one for drinking water and one for flushing water. The principles to be observed in the installation of the tanks are:—

(*a*) The tanks must be protected from the weather, especially the heat of the sun. To this end the tanks may be placed in an upper storey, or if placed on the roof, must be provided with a covering. Alternative methods are shewn on the drawing.

(*b*) From the *bottom* of the tank,—not the side,—one large sized down pipe is to run right down to the ground, terminating in a valve of the same size. Branches are to be taken off this main pipe to the various taps as required. The object of the large pipe to ground level is that the lower end of the pipe will act as a sump for collecting any sediment that may form. This may be removed periodically, and the tank washed out by simply opening the valve at ground level.

(*c*) Both the up and the down pipes should be fixed on the *north* wall of the house thereby getting protection from the sun.

It is a fact that in England storage tanks are often looked upon with disfavour. But the Eastern house and the European house are quite different. In England the storage tank has to be tucked away under a sloping roof and is always difficult of access for cleaning purposes. In Bengal all the roofs are flat, and in most cases the roof is made accessible by a staircase. A tank placed on the roof will therefore be easily accessible, and will not be forgotten.

The responsibility for the installation and maintenance of the roof tank will be placed upon the householder. This is arranged for in the draft rules.

In the case of a house in which the structure is too weak to carry the weight of a tank, a steel staging may be resorted to if the householder is prepared to pay for getting his water at an elevation. Otherwise a tank at ground level may be installed.

STREET TANKS.

For the street supply, storage is again necessary. Tanks on pedestals may be placed at road junctions or other convenient points. Two designs for tanks are shewn at figures 1 and 2 on Plate VI,—many other arrangements are possible. In the case of a narrow bazar street where there is no room for tanks, one larger tank may be placed on the nearest open space, and a pipe run along to feed a few standposts in the street. The tank may be placed about 8 feet above ground, and may be made into a street shelter, as shewn at figure 3 on Plate VI. In each case, the number of people likely to draw water from a particular tank must be estimated, and the connecting pipe, with its check pipes, must be regulated so that the quantity of water to which they are entitled according to the design of the scheme passes into the tank during the hours of pumping. In most Bengal towns people of one community live together in one section (or *mahallah*) of the town. Arrangement would always be made so that each *mahallah* would have at least one tank to itself, and communal difficulties would thereby be obviated.

All tanks, either in the street or on roofs, will of course be provided with ball-valves, so that, when water is not being drawn off at the maximum rate provided for, the ball-valve will rise on the tank becoming full, and wastage will be prevented.

FIRE PREVENTION.

In practically none of the waterworks in Bengal have fire hydrants been fitted. Very few of the smaller municipalities possess fire appliances of any description. Even if fire engines or hand pumps were installed, there are generally plenty of tanks from which water could be drawn, so that the waterworks would not be called upon to supply water. Nevertheless, fire hydrants could be provided in the proposed system, though of course they would have to be kept securely locked. A water jet would be more efficient in this system owing to the higher pressure. The reducing valves could be of the type in which a fitting is provided whereby they can be temporarily thrown out of action, and the full pressure given to the zone. The feeding of roof tanks would of course be upset for the time being, but that would be only of rare occurrence.

STREET WATERING.

The best system for watering the streets is to use water-carts, and these could be conveniently filled at the large tanks, as illustrated in figure 3, Plate VI. The system of watering by jet is not a good one in any case, as it leads to waste of water and reduction of pressure due to leaking ground hydrants, and also breaks up and washes away the road surfacing material.

MODEL RULES.

A suggested code of Rules is given in the appendix. The various points in connection therewith can be seen from the following explanation of the rules, taking them seriatim :—

Preamble.—This is similar to the preamble of the existing rules.

Rule 1.—This is self-explanatory. It is considered advantageous to have the house connection rules printed on the back of every application form, so that there can be no question of a householder not having seen the rules.

Rule 2.—A fee will be taken, as in the present system. The amount of the fee will however be less, as explained hereafter.

Rule 3.—This rule must be more rigidly enforced in the proposed system than in the present system.

Rules 4 & 5.—Since the regulation of the quantity of water depends on the service pipe, it is important that the Municipality shall retain control of the same. Hence the proposal that the service pipe and its appurtenances shall be provided by the Municipality and shall remain its property.

It is proposed that the sketch plan of a typical installation be multiplied off, and that a copy of the plan be given to every householder who takes a connection. There will then be no excuse for failure to understand how the wash-out pipe should be fixed, the tank protected from sun heat, etc., etc.

Rules 6, 7 & 8.—The cost of the part of the house connection to be paid for by the householder will be a little more than the amount he has to pay according to the present system. He will not have to pay for a meter, nor the service pipe up to his roof, but the cost of the tank, with protection over it, etc., will be greater than the savings. If the total cost of a house connection under this system is to be greater, the system will not be popular. It is therefore proposed that the fee payable under rule 2 shall be reduced so as to make the total cost of an average connection about the same as at present.

The quality and the capacity of the storage tank (or tanks) will be left to the decision of the householder. Some will prefer to spend a little extra money and have ample storage and tanks of stronger material, while others will do the work as cheaply as possible. This does not matter to the waterworks,—the tank belongs to the householder,—a cheap tank will not last so long as an expensive one. The capacity makes no difference to the daily quantity of water supplied. A capacity of about one day's supply will generally be found sufficient.

The cost of an average connection works out to between Rs. 270 and Rs. 300, which is about Rs. 100 more than the cost of a connection on the present system.

Rule 9.—Under the proposed new system, water rate will be imposed as heretofore according to the valuation of the holding. The service pipe will be made such that approximately the daily quantity of water to which the householder is entitled will reach the storage tank during the hours of pumping,—that amount and no more. Several difficulties in the present system of water supply are met and dealt with by this rule:—

(*a*) At the lower limit, the case of the poor man who lives in a very small house and cannot afford to pay much water rate is dealt with, in that however small the water rate he pays, he will not get less than 120 gallons per day.

(*b*) At the upper limit the case of the rich man, living in a big house, is dealt with. Owing to the large amount of water rate he pays, he would under the old rules be entitled to a great deal more water than he can possibly use legitimately, and his household would therefore waste it. In these rules a limit is set to the quantity of water to be given.

(*c*) The case of the man of moderate means but with a large family is also dealt with. Such a man would probably have to live in a small house, and if he received only the amount of water to which he would be entitled by the assessed water rate, the amount might not be sufficient for the number of people in his household. But in this rule there is nothing to prevent him from voluntarily paying a higher water rate than that at which he is assessed, thereby entitling himself to a larger daily water supply. It is only fair that he should pay more for water if he requires more. Water which has been pumped and filtered costs money, and must be paid for, and the fact that a man has a bigger family than his neighbour is no reason why he should have a greater supply of water unless he pays for it,—just as with food or clothing.

(*d*) In the rule, the words "shall be entitled to," which appear in No. 15 of the old rules, are retained. This does not involve the Municipality in any legal obligation to supply the exact quantity of water specified, although it implies that they will endeavour to supply that amount.

Rules 10, 11, 12 and 13.—These rules are framed to deal with special occasions such as marriage ceremonies, etc., when a householder may have for a short time a large increase in the number of inmates of his house. On these occasions a man is quite prepared to pay extra for extra water obtained. The rates of payment in rule 10 should however be made fairly high so as to discourage the retention of the temporary connection for longer than necessary. The lump sum prepayment stipulated in rule 10 will be based on the cost of putting in the connection and subsequently removing the same, plus hire and depreciation charges for the materials used.

The service pipe referred to in rule 11 will again be provided with check pipes so that only the daily quantity of water agreed upon can flow to the tank.

If at any time the quantity of water a householder is getting from his ordinary connection, or from his ordinary connection and temporary connection combined, is insufficient for his requirements, it must be remembered that the nearest street tap is always available to him, and that he can send someone to fetch water from it.

Rule 14.—This is a similar rule to No. 16 of the old rules.

Rule 15.—This is a useful improvement on the latter part of the rule 6 of the old rules.

Rule 16.—Is the same as rule 19 of the old rules.

Rule 17.—Is a protective clause which may be usefully inserted.

CONCLUSION.

With the proposed system, the following advantages will be gained :—

(*a*) Meters will be unnecessary, and with their abolition the cost of reading them, of testing them, of repairing them and of sending out bills for excess consumption and realizing the money, will be avoided.

(*b*) Economy in the use of water by a household will be automatically obtained, with the consequent possibility of maintaining an efficient waterworks at moderate cost.

(*c*) The boon of continuous supply in the house is given.

(*d*) Schemes can be carried out at a cost a little lower than in the present system. The cost of central storage will in some cases be entirely saved, and in other cases largely so, and the cost of the trunk main will be reduced. Against this saving the street tanks, the service pipes and spare tanks are to be paid for, together with a slightly increased cost of machinery, but on the whole there will be a saving. In connection with this, the reduced income from house connection fees must also be considered.

It may be argued that in a waterworks of this description, as with any other, failure will soon occur owing to the demand getting ahead of the supply. But it should be noted that with the proposed arrangement, the probable course of events will assist in bringing about the proper remedy for increased demand. The works will of course be designed to supply a certain number of street and roof tanks. As soon as that number is exceeded, the very first effect will be that the owners of the biggest and highest houses will find that they are not getting their full daily allowance. The owner of such a house, if not actually a municipal commissioner, will be an influential man, and he will at once demand to know the reason of his shortage of supply. Enquiry from the waterworks superintendent will elicit the fact that the reason is simply that a few connections have been given beyond the capacity of the waterworks. Such owner will therefore use his influence to ensure that no more connections are given until the supply is increased, and the municipality will be urged to prepare and finance a proper extension scheme. By a properly executed extension scheme the increased demand can of course be met.

APPENDIX.

REVISED MODEL RULES.

So long as the Commissioners deem it practicable and consistent with the maintenance of an efficient water supply, they may grant to any owner or occupier of a holding paying a water rate imposed under the provisions of Part VII of the Bengal Municipal Act, 1884, on the annual value of such holding, when such annual value is not less than Rs.   , a connecting pipe from the service pipes of the Commissioners for the purpose of leading water to such holding for domestic purposes only, subject to the following rules and conditions:—

1. The owner or occupier of any holding requiring water to be laid on to such holding for domestic purposes must apply for the same on the printed form 'A' to be supplied free of cost, at the Municipal Office. The form states the rules on which a house connection will be given, and the owner or occupier must sign the statement undertaking to observe the rules before a house connection will be given.

2. A fee of Rs....................................must be paid to the Commissioners by such owner or occupier for each connection to a municipal main supply pipe before any work is commenced, such fee to be in addition to all other costs and charges imposed under these rules.

3. Each holding must have a separate connection to the municipal main supply pipe, and extension from the communication pipe of one holding to another holding shall not be permitted.

4. The connection shall consist of two portions:—

(*a*) the service pipe, comprising ferrule, stop-cock, check pipes, and connecting pipe from the street main to the roof of the house or other point at which the storage tank is fixed; and

(*b*) the storage tank (or tanks) suitably covered and protected, with locked lid, ball valve, stop valve, overflow pipe, outlet pipes, taps, wash-out valve, and other necessary accessories. A typical storage tank with appurtenances is shewn on the attached sketch plan.

5. The portion (*a*) referred to in rule 4 shall be provided and fixed by and at the expense of the Municipality, and the pipes and fittings shall remain the property of the Municipality. The owner or occupier shall not permit the service pipe or any part thereof to be altered, removed, or interfered with by any person other than an authorized representative of the Municipality.

6. The portion (*b*) referred to in rule 4 shall be provided and fixed at the expense of the owner or occupier, and must be maintained by him in good working order.

7. The storage tanks referred to in rule 4 (*b*) must be durable and water-tight, and the ball valve and other fittings must be exact duplicates of standard samples kept in the office of the Commissioners and approved by them at a meeting. The storage tank or tanks must be periodically cleaned and sterilized at the expense of the owner or occupier.

8. Every storage tank shall be fitted with an overflow pipe, the end of which shall project over the wall of the house and shall be placed in a conspicuous position. Discharge of water from the overflow means that the ball valve is failing to function, and the owner or occupier must undertake to notify the waterworks officers every time he finds such discharge occurring.

9. Every owner or occupier of any holding, in respect of which a connection has been made under these rules, shall be entitled to a supply of water in proportion to the water rate paid by him in respect of such holding, according to the following table:—

Quarterly amount of water rate paid.				Daily quantity of water to which entitled.
	Rs. A.		Rs. A.	
Not Exceeding	3 8			120 gallons.
Exceeding	3 8	but not exceeding	3 12 ..	130 ,,
Do.	3 12	Do.	4 0 ..	140 ,,
Do.	4 0	Do.	4 4 ..	150 ,,
Do.	4 4	Do.	4 8 ..	160 ,,
Do.	4 8	Do.	4 12 ..	170 ,,
Do.	4 12	Do.	5 2 ..	180 ,,
Do.	5 2	Do.	5 8 ..	190 ,,

Quarterly amount of water rate paid.							Daily quantity of water to which entitled.
	Rs.	A.		Rs.	A.		
Exceeding	5	8	but not exceeding	5	14	..	200 gallons.
Do.	5	14	Do.	6	4	..	210 ,,
Do.	6	4	Do.	6	10	..	220 ,,
Do.	6	10	Do.	7	0	..	230 ,,
Do.	7	0	Do.	7	8	..	240 ,,
Do.	7	8	Do.	8	0	..	250 ,,
Do.	8	0	Do.	8	8	..	260 ,,
Do.	8	8	Do.	9	0	..	270 ,,
Do.	9	0	Do.	9	8	..	280 ,,
Do.	9	8	Do.	10	0	..	290 ,,
Do.	10	0	Do.	10	8	..	300 ,,
Do.	10	8	Do.	11	0	..	310 ,,
Do.	11	0	Do.	11	8	..	320 ,
Do.	11	8	Do.	12	0	..	330 ,
Do.	12	0	Do.	12	8	..	340 ,,
Do.	12	8	Do.	13	0	..	350 ,,
Do.	13	0	Do.	13	8	..	360 ,,
Do.	13	8	Do.	14	0	..	370 ,,
Do.	14	0	Do.	14	12	..	380 ,,
Do.	14	12	Do.	16	0	..	390 ,,
Do.	16	0	Do.	18	0	..	400 ,,

For consumers paying more than Rs. 18 per quarter as water rate, the number of gallons of water to be given per day will be calculated as—

$$\frac{200 \times}{9} \text{ the quarterly water rate paid (in rupees).}$$

10. In case the owner or occupier requires for special occasions or otherwise more water than the amount to which he is entitled according to rule 8, he may apply to the Commissioners in form 'B' (obtainable at the Municipal Office free of charge) for a temporary connection. He must undertake to pay in advance

the sum of Rs. per tank, and also to pay weekly the following charges during the whole time he retains the temporary connection :—

(*a*)	for a supply of	200	gallons per day	Rs.	0 8	per day.
(*b*)	Do.	300	Do.	,,	0 12	,,
(*c*)	Do.	450	Do.	,,	1 0	,,
(*d*)	Do.	600	Do.	,,	1 4	,,
(*e*)	Do.	750	Do.	,,	1 8	,,
(*f*)	Do.	900	Do.	,,	1 12	,,
(*g*)	Do.	1100	Do.	,,	2 0	,,

The application must also state the number of weeks for which the connection is required.

11. On receipt of the application, with the signed agreement and stipulated prepayments as per rule 10, the Commissioners shall forthwith instal within the compound and at a level two feet above ground an additional storage tank (or tanks) of 300 gallons capacity with ball valve and two taps fixed to each tank. They shall connect the same to the street main by a service pipe or pipes, and do all other work necessary to commence and maintain the supply.

The Commissioners shall keep in stock a number of tanks, with pipes, fittings, etc., for the above purpose.

12. The payment referred to in rule 10 shall be made once a week. In case the owner or occupier fails to make the payment weekly, the Commissioners or their officers may at once enter the premises and remove the storage tank or tanks, temporary service pipes, etc.

13. Two or more such temporary connections may be taken if required, on payment of the additional costs and weekly charges.

14. The Commissioners may cut off the connection between any waterworks of the Municipality and any holding to which water is supplied from such works, or may turn off such supply, in any of the following cases, *viz.* :—

(*a*) if the holding is unoccupied;

(*b*) if the occupier fails to pay his water rate;

(*c*) if the occupier in any way interferes with, damages, or alters the service pipe; and

(*d*) if the occupier refuses to admit any officer duly empowered in that behalf into the holding for the purpose of making any examination or inspection of the service pipe or storage tank, or prevents such officer making such examination or inspection.

Provided that 24 hours' notice in writing of such examination or inspection may be demanded.

15. The work stipulated in clause 4 (*b*) shall be carried out by a person or firm employed by the owner or occupier and approved by the Commissioners. For this purpose the Commissioners shall grant licenses to approved persons or firms, who should preferably have had previous experience in plumbing work.

16. No connection shall be permitted to any holding unless and until the owner or occupier makes effective provision to the satisfaction of the Commissioners for draining away all waste water.

17. The Municipality will not be responsible for any interruption or diminution of water supply due to occurrences beyond its control.

FORM A.

....WATERWORKS.

APPLICATION FOR ORDINARY HOUSE CONNECTION.

To

The Chairman, and Commissioners,

.....................................Municipality.

Gentlemen,

I request you to lay a service pipe and supply water to me at ....

....

upon the terms and conditions stipulated in the house connection rules printed on the back hereof, which I have read and which I agree to observe and perform. I also hereby agree to pay in advance the fee of Rs........................according to Rule 2.

The amount of water rate payable quarterly, according to the annual value of the above holding is Rs........................, and the amount of water rate which I undertake to pay quarterly is Rs...... ....

Yours faithfully,

Witness.—

Signature......................................

Address......................................

Dated..................................

FORM B.

.. ..WATERWORKS.

APPLICATION FOR TEMPORARY HOUSE CONNECTION.

To

The Chairman, and Commissioners,

..................................Municipality.

Gentlemen,

I request you to fix a storage tank, pipes, etc., for a temporary connection according to Rules 10, 11 and 12 of the house connection rules at............ ....
....
.. ..

I send herewith Rs................................. ..... being the stipulated cost for making the connection and removing the same, including hire of materials.

I require an extra supply of..............gallons per day, and I hereby agree to pay Rs..................... per day for every day during which I retain the connection, and I agree to make the payment weekly.

I shall require the connection for approximately........... weeks commencing from.. ....
(date)

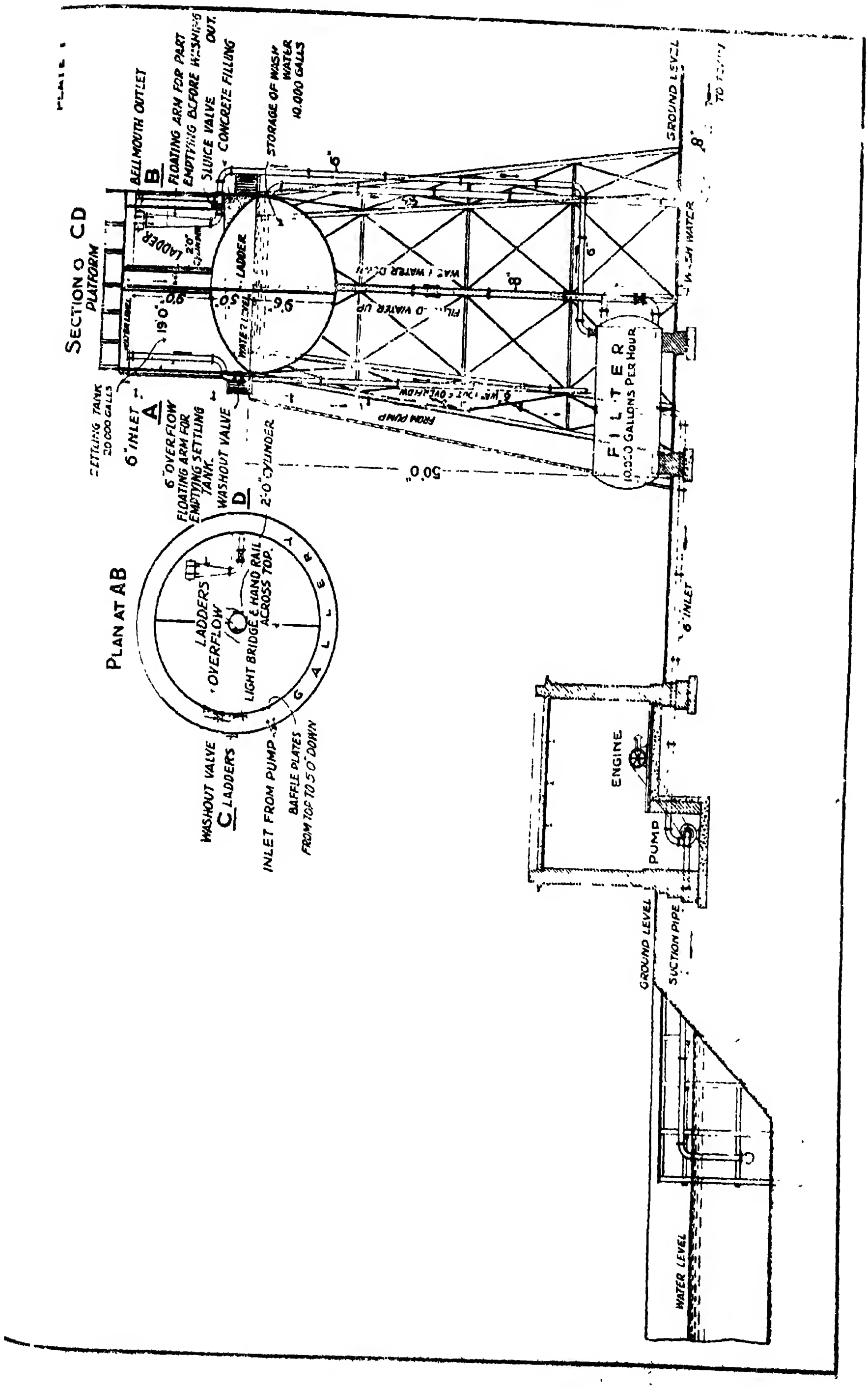
Yours faithfully,

Witness.—

Signature..................................

Address.....................................

Dated................................


SECTION O CD
PLATFORM
BELLMOUTH OUTLET
B
FLOATING ARM FOR PART EMPTYING BEFORE WASHING OUT.
SLUICE VALVE
CONCRETE FILLING
STORAGE OF WASH WATER 10,000 GALLS
LADDER
SETTLING TANK 20 000 GALLS
6" INLET
A
6" OVERFLOW
FLOATING ARM FOR EMPTYING SETTLING TANK.
WASHOUT VALVE
D
2-0" CYLINDER
FROM PUMP
50.0"
FILTER
10,000 GALLONS PER HOUR
WASH WATER
GROUND LEVEL
6" INLET
ENGINE
PUMP
GROUND LEVEL
SUCTION PIPE
WATER LEVEL
PLAN AT AB
LADDERS
OVERFLOW
LIGHT BRIDGE & HAND RAIL ACROSS TOP.
GALLERY
WASHOUT VALVE
C LADDERS
INLET FROM PUMP
BAFFLE PLATES FROM TOP TO 5'0" DOWN

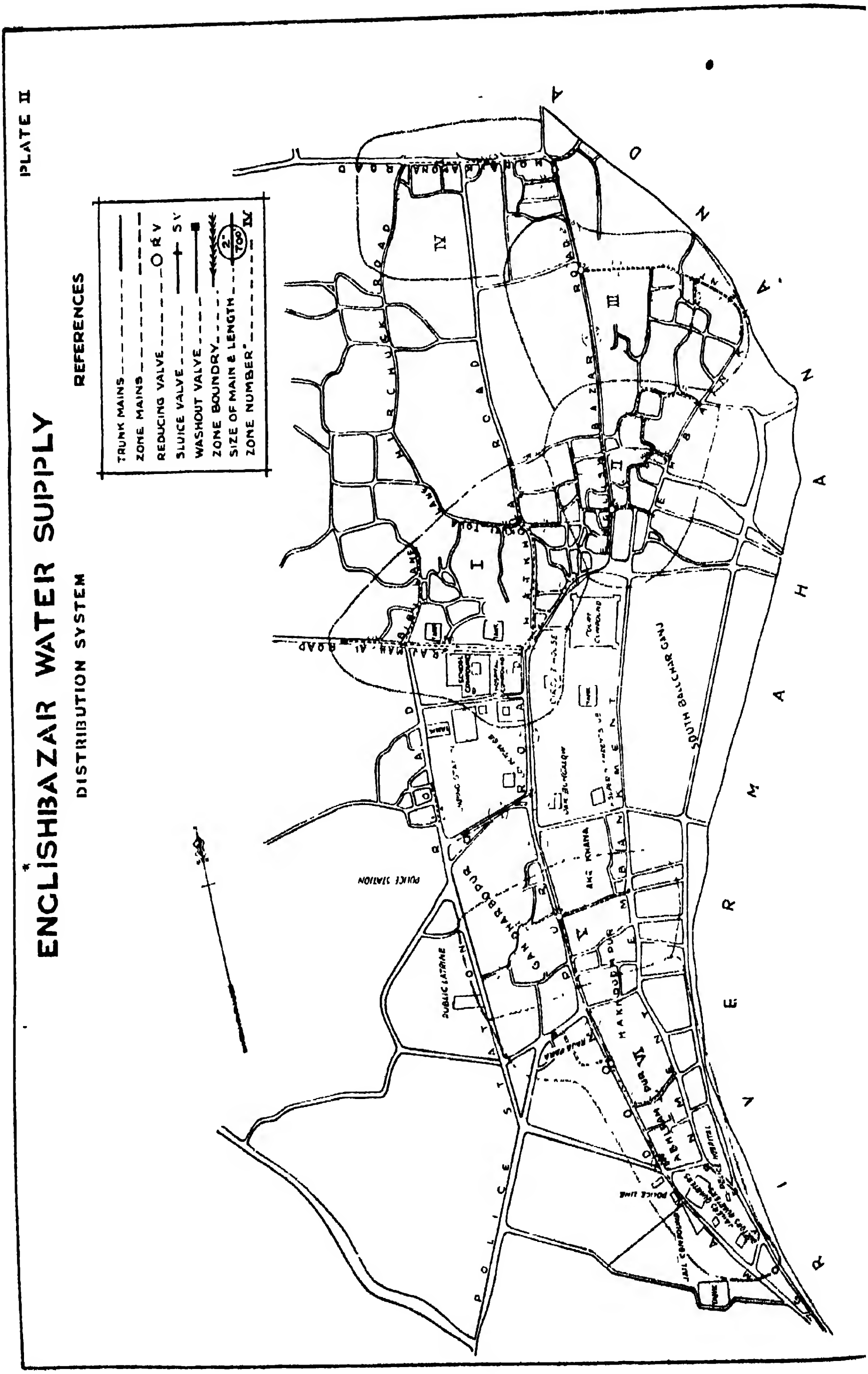


PLATE II
ENGLISHBAZAR WATER SUPPLY
DISTRIBUTION SYSTEM
REFERENCES
TRUNK MAINS
ZONE MAINS
REDUCING VALVE
SLUICE VALVE
WASHOUT VALVE
ZONE BOUNDRY
SIZE OF MAIN & LENGTH
ZONE NUMBER
POLICE STATION
PUBLIC LATRINE
SOUTH BALUCHAR GANJ
POLICE LINE
JAIL COMPOUND
MAHANANDA RIVER
POLICE STATION ROAD

PLATE III

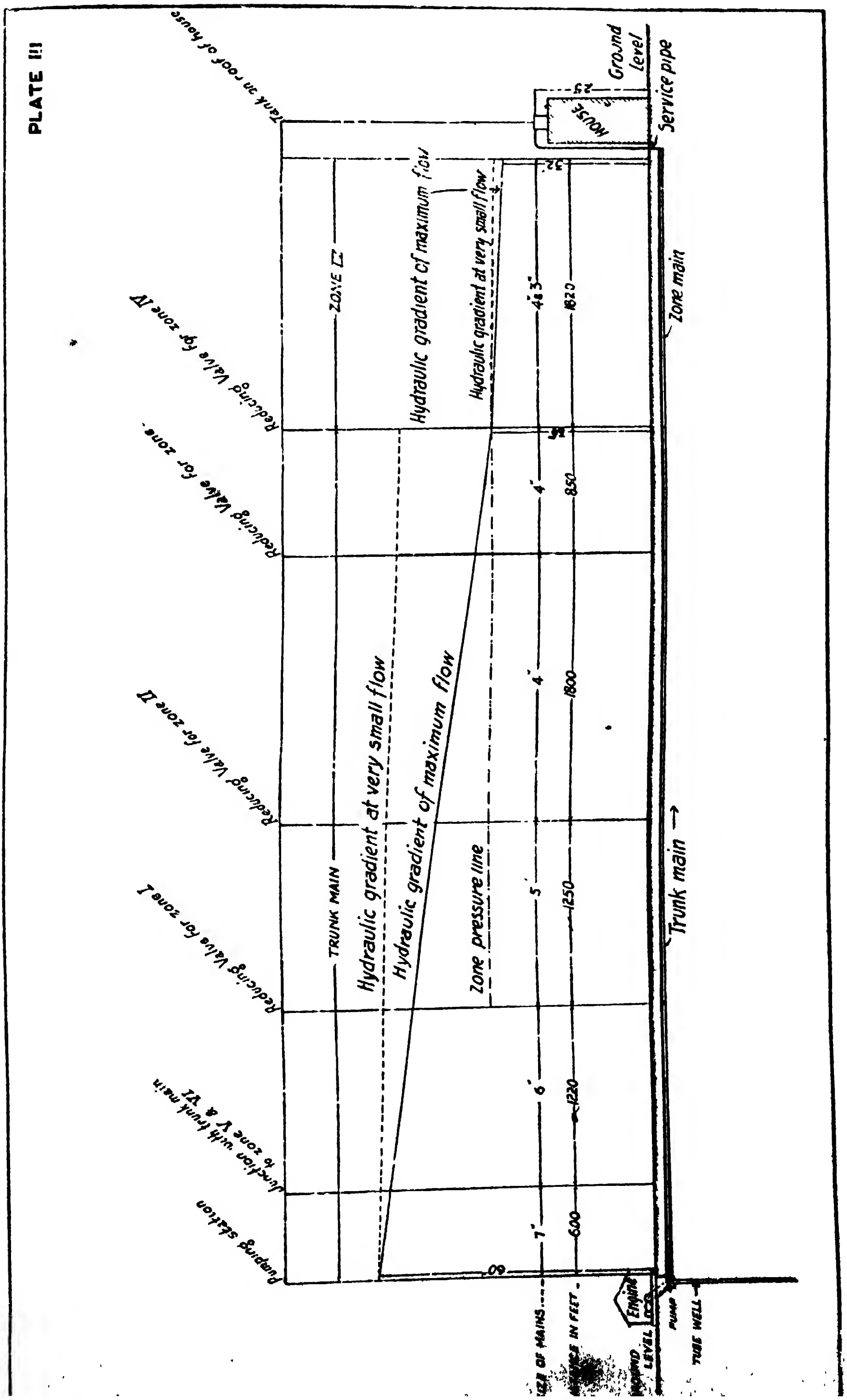

Tank on roof of house
Ground level
Service pipe
HOUSE
25
32
Zone main
ZONE VI
Hydraulic gradient of maximum flow
Hydraulic gradient at very small flow
1820
Reducing Valve for zone IV
Reducing Valve for zone
4"
850
4"
1800
Reducing Valve for zone II
TRUNK MAIN
Hydraulic gradient at very small flow
Hydraulic gradient of maximum flow
Zone pressure line
Trunk main →
5"
1250
Reducing Valve for zone I
6"
1220
Junction with trunk main to zone V & VI
Pumping station
7"
600
60
Engine
PUMP
TUBE WELL

PLATE IV

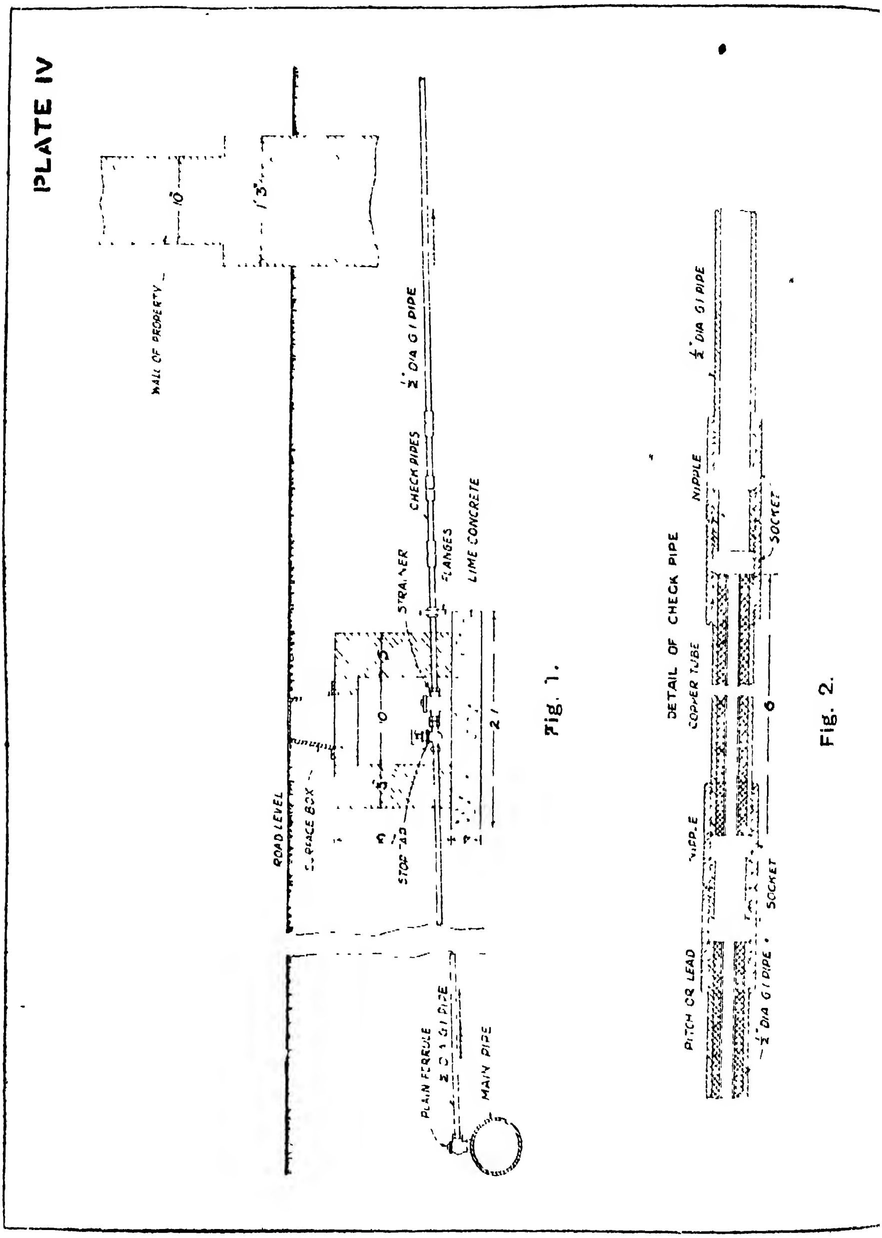
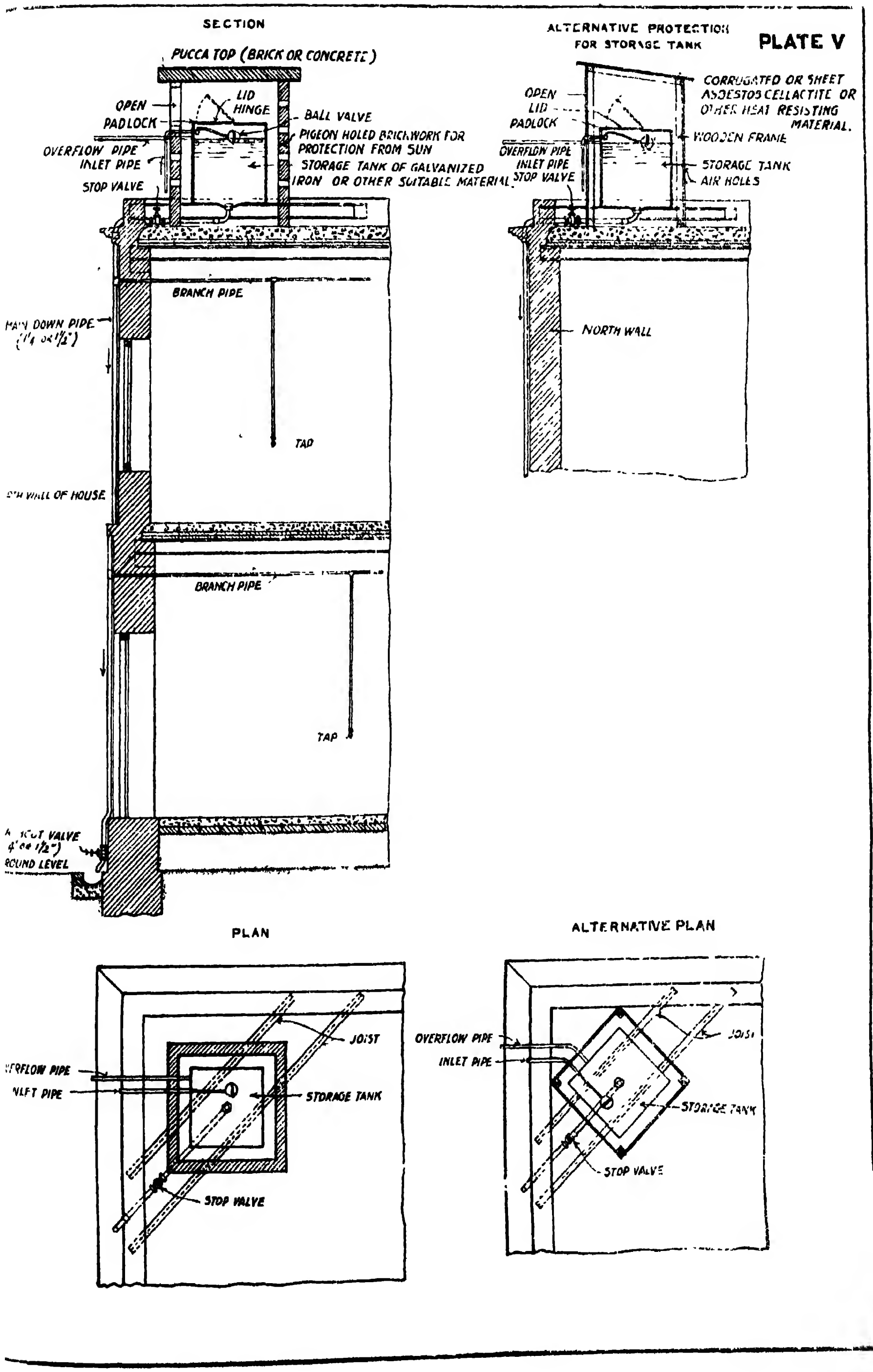


Fig. 1.

Fig. 2.

PLATE V


SECTION
PUCCA TOP (BRICK OR CONCRETE)
OPEN
LID
HINGE
PADLOCK
BALL VALVE
PIGEON HOLED BRICKWORK FOR PROTECTION FROM SUN
OVERFLOW PIPE
INLET PIPE
STORAGE TANK OF GALVANIZED IRON OR OTHER SUITABLE MATERIAL
STOP VALVE
BRANCH PIPE
MAIN DOWN PIPE
TAP
BRANCH PIPE
TAP
ROUND LEVEL
ALTERNATIVE PROTECTION FOR STORAGE TANK
OPEN
LID
PADLOCK
CORRUGATED OR SHEET ASBESTOS CELLACTITE OR OTHER HEAT RESISTING MATERIAL.
WOODEN FRAME
OVERFLOW PIPE
INLET PIPE
STOP VALVE
STORAGE TANK
AIR HOLES
NORTH WALL
PLAN
JOIST
STORAGE TANK
STOP VALVE
ALTERNATIVE PLAN
OVERFLOW PIPE
INLET PIPE
JOIST
STORAGE TANK
STOP VALVE

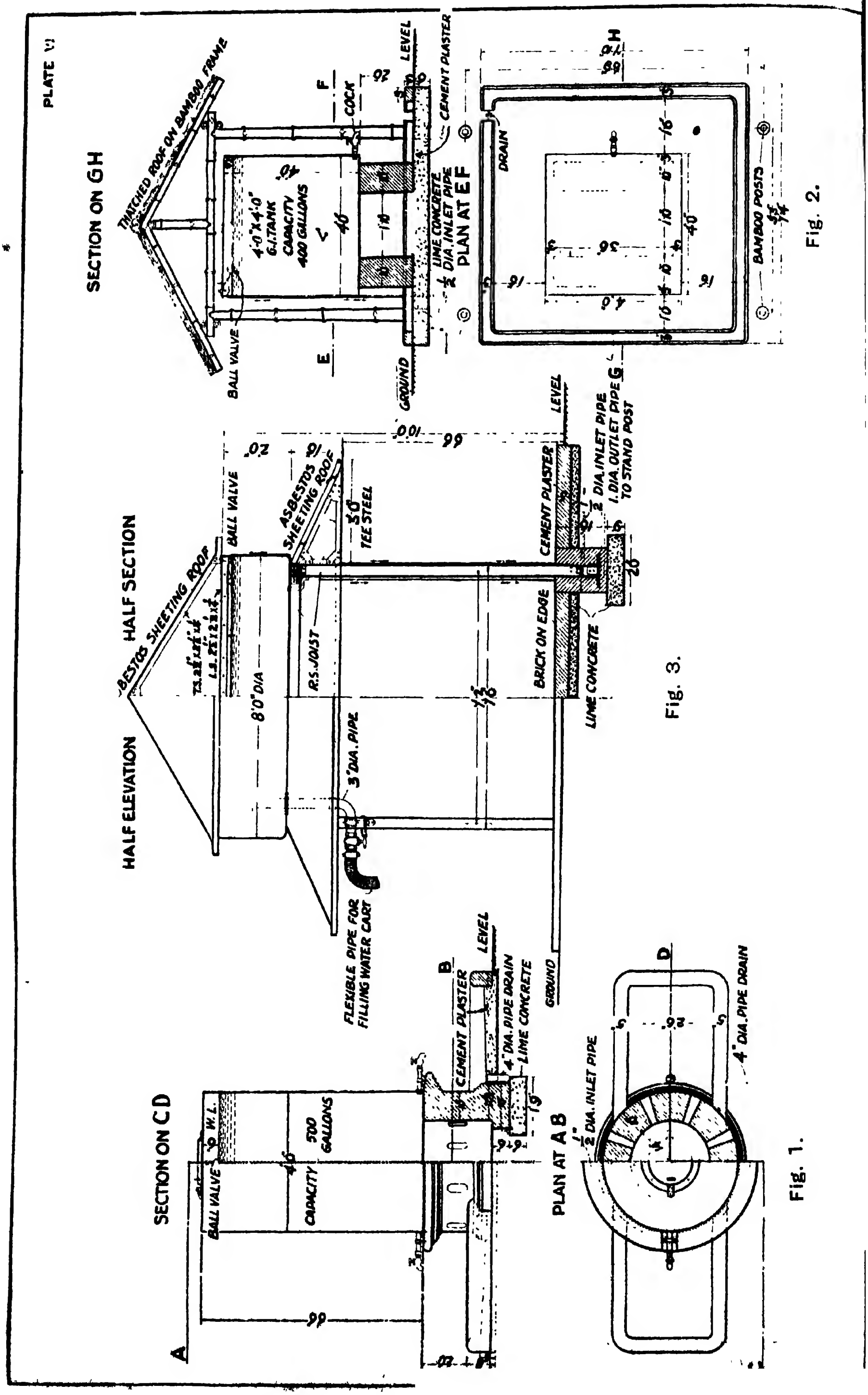


Fig. 2.

Fig. 3.

Fig. 1.

DISCUSSION ON WATER SUPPLY BY DECENTRALIZED STORAGE.

Correspondence.

Mr. G. Bransby Williams.

Mr. G. Bransby Williams remarked that Mr. Griffin had gone to much trouble to explain his proposals as fully as possible in his paper and had exercised considerable ingenuity in devising the method of water distribution in mofussil municipalities, which he had described, and which, he hoped, would obviate some of the difficulties experienced with the present system. He had, however, not sufficiently taken into consideration some of the practical points involved. The fundamental fact to be borne in mind was that most of the trouble with the waterworks in this country arose from the failure of municipal authorities and ratepayers to appreciate the economic aspect of the question. The initial cost and the maintenance charges of a waterworks were nearly in proportion to the quantity of water supplied. The magnitude of the supply was therefore limited by the amount of money the municipality concerned could afford to spend on carrying out a waterworks scheme. When a scheme had been completed and was in operation this limitation was entirely disregarded. Applications for private house connexions were made in large numbers and were usually granted by the municipal commissioners to all who could afford to pay the cost of putting them in. When the water had been laid on to a house the householder allowed, or even encouraged, waste, he resented all measures that might be adopted to prevent it, or make him pay for the water wasted, whilst his attitude was generally sympathized with, by the municipal commissioners, and acquiesced in by the members of the public, who could not afford house connexions, and who were therefore the parties who were most directly injured by the waste in the houses of their more favourably situated neighbours. The consequence was that there was no weight of public opinion against the wasters. In fact it was all on their side, and the unchecked waste in the connected houses might cause the water consumed per head to be as much as 20 times, or even more, than that which the people who had to go to the street standposts were able to obtain. In such circumstances the waterworks were called upon to supply more water than they were designed for, the machinery and filters were overtaxed, the supply in the outlaying parts of the town became inadequate and the waterworks fund bankrupt. These disastrous

Mr. G. Bransby Williams.

results could be prevented if the parties concerned could be brought to understand that water was a commodity that cost money like electricity and that it was just as reasonable that it should be paid for as that the latter should. If the water supplies of the Indian towns were in the hands of private companies, as in the case in many other parts of the world, there was no question that the users would be made to pay in proportion to the benefit received by them, and that the meter system would be in full and successful operation. There was no difficulty in working it except the attitude of mind of the municipal commissioners and the ratepayers concerned, as was shewn by the examples of Berhampur (under Government control), Utterpara and Kalimpong. But until that attitude changed, no system of control of waste had any prospect of succeeding in its object. As regards Mr. Griffin's proposals, far from their being likely to be more popular than charging by meter, the exact opposite was the case. So long as there was a physical possibility of getting water from the mains the householder could, if he so desired, take what he wanted even if there was a meter on his connexion. He could trust to his meter either not being read, or, if it was, to his being able to evade payment. If, however, the supply was actually restricted to a definite daily quantity, that was the end of it, and, however great his real or imaginary need, he could get no more.

It did not require much acquaintance with Bengal towns to know that in such circumstances the outcry on the part of the gentlemen who found their cisterns empty when their neighbours' were still full would be so tremendous that no municipality would be likely to offer opposition to such a volume of public opprobrium. It might be safely prophesied that if Mr. Griffin's proposals were put into practice, at least half of his check pipes would have been removed, either with official sanction or non-official connivance, within a month.

Apart from these fundamental objections there were engineering difficulties in the way of the successful operation of the scheme. It involved adjustments of the rate of flow to a most complicated variety of conditions of pressure and quantity to be delivered. It depended on the accurate working of a number of pressure reducing valves. It necessitated elaborate arrangements for discharge into tanks at different heights above ground, at all sorts of pressures, through various lengths of supply and check pipes, with minute apertures. It presupposed conditions that did not exist in any Bengal waterworks, and the continuance unchanged of those conditions throughout the daily and seasonable fluctuations in the demand. Any appreciable alteration in the pressure in the mains

Mr. G. Bransby Williams

would operate inequitably upon neighbouring houses; for the reduction in the flow into a tank on the roof of a high house would be proportionately much greater if the pressure in the main were diminished than it would be in the case of a tank on the roof of a low house.

Whilst he could only express admiration for the care and thoroughness with which Mr. Griffin had gone into this question, he regretted that he could only come to the conclusion that his proposals were quite impracticable and unworkable.

The only really satisfactory course in regard to new mofussil water supply schemes in this country, would be to confine the supply to street standposts only until the local authorities had learnt the elements of water supply economics. It had been found by the Director of Public Health that the effect upon water borne disease of a street standpost supply was generally as beneficial as that of one in which water was laid on to some of the houses. In fact a waterworks, which gave a supply evenly distributed through standposts in all parts of the town, was far more effective in preventing disease than one which provided a copious supply in a few houses whilst outlying districts got little water or none. House connexions had been frequently introduced under the impression that the fees obtained from the house owners were an assistance towards financing the scheme. So long as these fees were considered the final discharge of the financial obligation of the owners on account of the connexions this idea became a fallacy. Take as an example, a waterworks scheme for a town of 10,000 inhabitants, drawn up for a supply strictly limited to street standposts. It would be sufficient for this purpose to give a daily quantity of 50,000 gallons. If it was desired to give 200 house connexions, and the inhabitants of the connected houses number 2,000, and if they were not metered, an extra supply to those persons of 25 gallons per head would be necessary. That is to say the supply would have to be doubled and would be 100,000 gallons a day instead of 50,000 gallons. The initial costs of the schemes would naturally depend upon local conditions, but for the sake of argument they might be taken as Rs. 90,000 for the first and Rs. 1,70,000 for the second. The working expenses would be, say, Rs. 5,000 and Rs. 9,000 a year. For the sake of 200 houses the capital and the annual working costs would therefore have been increased by Rs. 80,000 and Rs. 4,000 respectively. Unless each connected householder were called upon to pay a fee of Rs. 400, which is much in excess of the figure usually demanded, the introduction of the house connexions would be a loss merely from the point of view of capital cost, leaving the extra working expenses of Rs. 4,000 a year, towards which nothing would be obtained from the householders, to be met by the general body of

Mr. G. Bransby Williams.

ratepayers. From a financial point of view the introduction of unmetered house connexions was an unsound proposition. From the public health standpoint they had seldom any advantage, and might be detrimental. They were merely a convenience for a limited number of individuals at the expense of the public at large, and until this was realized, and the persons benefited were made to pay the fair share of the cost of the water supplied, the policy of permitting house connexions in small schemes ought to be definitely abandoned.

Diwan Bahadur A. V. Ramalinga Ayyar Avl.

DIWAN BAHADUR A. V. RAMALINGA AYYAR AVL. remarked that at the outset he would congratulate Mr. Griffin on the attempts he had made in suggesting a possible solution of the vexed question of metering. He had no doubt this paper would give much food for thought and discussion.

Deficiency in municipal water supplies was not uncommon in this province. Most of the schemes were designed on financial grounds to supply a limited quantity of water for an assumed prospective population. It was not infrequent that the actual population was in excess of the anticipated population assumed in designing the schemes. This was one of the reasons for the inadequacy of the supply. When once the scheme was put in operation its scope was widened by extension of the distribution system brought about mainly by the appreciation of the people on the advantages of a protected water supply. This was another reason for the deficiency of supply. Most of the schemes were designed again on financial grounds as street fountain schemes. The introduction of house connexions later on increased the consumption of water and thereby depleted the supply provided for distribution through street fountains. The waste and misuse of water through house connexions, particularly in those which were not metered, formed the most important reason for the deficiency of supply as experienced in the municipal water supplies everywhere.

The opposition to metering seemed to be based on an erroneous idea that once the municipal water supply was introduced, the ratepayers were entitled to an *unlimited free supply* of water in the same way as every citizen was entitled to consume without any let or hindrance the other necessity of life, *viz.*, air. But the analogy of the free supply of the prime necessities of life, *viz.*, air and water, was not extended to electric supply managed on business lines. If water and air form the free gift of god, so also light. Why then observe strict business principles in the case of electric supplies and adopt different ones for municipally owned water works?

Diwan Bahadur A. V. Ramalinga Ayyar Avl.

The main curse of municipally owned water works was the unbusinesslike methods of both maintenance and management. It was not realized that water works finance should stand on its own bottom.

Several methods of discovering waste and misuse of water and stopping it, had been suggested and adopted in practice with varying results, but it was generally admitted on all hands that metering every private service connexion was the only practical method of solving the problem. *Per contra*, it was argued that the introduction of meters in house service connexions pre-disposed people to use a much smaller quantity than what was required for healthy living and, in consequence the object of the introduction of protected water supply, *viz.*, to ensure the healthiness of people was defeated. In this argument it was forgotten that there was what was known as a minimum free allowance based on the annual rental value of the property.

This more or less fixed the standard of sanitary requirements of individual tenements. It was also urged that in London the premier city of the world metering domestic services was not favoured. True, but was the civic conscience of our people anywhere near that of those obtaining in that country? Till some satisfactory method of overcoming this difficulty of metering was found, the only method of checking the waste and abuse of public water supplies was metering. This was, to his mind, the only practical solution.

Mr. Griffin's system was open to objection in that the check pipes could not be satisfactorily determined and fixed in practice; for, the minimum bore fixed in the first few connexions on a main might be found inadequate when several more connexions were made in that main proportionate to its carrying capacity. During the hours of maximum demand, a general low pressure might be experienced unless the water was pumped to a height more than that was contemplated in the scheme as designed.

Mr. Griffin said that "the ends of copper tubes must not of course be bell mouthed." The reason was not obvious.

The introduction of independent service tanks in houses was recognized to be retrograde measure of sanitary reform, fraught with serious danger of contamination of supplies. Any scheme suggested as an alternative to metering should not tend to afford opportunities for the deterioration of the quality of water during transit from the headworks till it was drawn for consumption.

In regard to his suggestion of street tanks the determination of the actual number of people likely to draw water from a particular tank with any pretence to accuracy, would be extremely difficult in practice.

Diwan Bahadur . V. Ramalinga Ayyar Avl.

With reference to fire hydrants being provided in the proposed system their utility in a scheme where a limited number of hours of pumping was adopted would be of doubtful value. The period when fire normally occurred was during the nights, and pumping was then generally stopped in these direct pumping systems. How then could the fire hydrants be of any practical use?

As regards the proposed model bye-laws, rule 9 (b) did not, to his mind, appear to have been based on correct data.

On the whole Mr. Griffin's paper stimulated one's thought and ideas in regard to prevention of waste and he had no doubt that many members would take part in this discussion and bring about a satisfactory solution of this important problem relating to municipal water works. If that was done the entire credit was due to Mr. Griffin.

r. F. C. emple.

MR. F. C. TEMPLE remarked that the system proposed by Mr. Griffin had already been partially introduced in Jamshedpur as being the only system that really prevented waste on house connexions. The system of check pipes for regulating the flow of water into the house storage tank was very ingenious and probably far more efficient than a valve in a locked and sealed box. The variation on Mr. Griffin's proposal that there should be two separate tanks for houses with sanitary fittings was to put separate outlets in the same tank at different levels. The usual practice in Jamshedpur was to put the kitchen and servants' tap half way up the tank and the connexion for house fittings at the bottom. The Hume Pipe Company made reinforced concrete tanks of various sizes with connexions arranged in that way.

A variant on the street tank proposed by Mr. Griffin was an arrangement known as a Rotary Bailer, one pattern of which was patented by R. M. Hughes and the other by A. T. D. Anderson both of the Bengal-Nagpur Railway. In both these a small mechanical apparatus placed in a constant level tank had to be operated by the person wishing to draw water. This had been found a far better preventive of waste than any other form of street stand pipe yet tried.

r. R. M. upta.

MR. R. M. GUPTA thought that there was very little doubt that by adopting the proposed system of supply most of the advantages mentioned by the author would be gained. But the method of prevention of waste had been carried too far, and was likely to cause inconvenience to the consumer.

Admittedly the demand for water varied considerably from time to time and even in the different hours of the day. But according to that system, the rate of supply which one could expect

from the service pipe was constant. The author suggested that this variation in demand would be met by storage in the house tanks. But this might not meet the difficulty. For example, a householder getting say about 240 gallons per day at the rate of 30 gallons per hour might have his tank almost empty at night. He required about 65 to 70 per cent of the water in the morning but he would not be able to get this amount of water (150 gallons) in less than 5 hours' time. He required 10 gallons for his bath, he would have to wait 20 minutes to get a full tub. In such cases the author suggested additional storage but that would in all probability mean additional wastage and also it was not understood how the ball cock arrangement would have any beneficial effect in preventing waste, where additional storage was used. **Mr. R. M. Gupta.**

To minimise the effect of inflexibility of supply, he suggested that arrangements be made so that the tank was filled up during the early hours of the morning. This would effect a further check on waste, for less water would be used in washing tanks, etc., which should of course be done periodically but not every day. He would mention that water from chowbatchas was drained out in the morning not only because of dirt or other polluting matters but also for the reason that people in this country have an aversion for using "stale" water, *i.e.*, water left from overnight. The latter was the stronger reason.

As regards design, theoretically since the supply to the consumer was at a constant rate, there could not be any objection to the mains being designed to deliver at the average rate But it would be better to design the pipes to deliver at twice the average rate, as was usually done not only for overcoming friction losses but also for providing for future unforeseen increase of supply.

(1) As regards check pipes, which would be fitted after making trials, he thought it would not be as easy a matter as the author suggested. For each connection, trials would have to be made to get the proper size check pipe.

(2) The discharge through the check pipes was likely to be affected when the pipe became old.

(3) A large number of connections made afterwards at the upper end of the pipe would also affect the discharge.

These two reasons would tend to diminish the amount of supply to which a householder was entitled.

Lastly water rates and taxation and incidence of taxation, though not strictly within the sphere of engineers, could not be ignored altogether.

Mr. R. M. Gupta.

The mode of taxation on the basis of valuation of holdings was not on an equitable basis but could not be helped under the peculiar circumstances obtaining in India. But if this method was accepted as the basis of water rates, it was necessary that, in spite of rich men paying higher taxation, they should not be entitled to more water than the fixed rate *per capita*—the more water a man got the more would be the tendency to waste. The rich man who could really afford to pay for the water consumed by the poor was benefited indirectly.

The amount of supply to houses should be calculated according to the capacity of the house and possible requirements. The whole object of the water supply scheme being to supply the individual with a fixed amount of potable water for his domestic purposes, there was no reason why the poor or the middle class man with a large family who was almost in the same category with the poor should not be supplied with the same quantity of water as the rich.

In conclusion, but for the objectionable features, namely, the inflexibility of supply, this method of preventing waste by restricted supply would be very suitable for conditions generally prevailing here in Bengal.

The other method of preventing waste was by increasing the supply and giving a continuous supply. This would ultimately mean extra recurring charges more than the amount saved by preventing wastage of water.

But if the municipal authorities really wished to prevent waste, wholesale metering must be done, and care must be taken to see that the meters were in working order and regularly read. This would incidentally bring in more revenue.

Mr. E. F. White.

Mr. E. F. White remarked that the extremely interesting paper entitled "Water Supply by Decentralised Storage" dealt with a very important subject for the people in Bengal, namely the provision of an adequate supply of pure water by a system expressly designed to reduce costs and prevent waste.

Storage Tanks. The system proposed in the paper would appear to be such as would need a small initial outlay as compared with the use of a Central Storage Tank. The latter, if of ample capacity and if elevated to give the requisite pressure, must form a very considerable portion of the capital cost of a water distribution system.

It was probable that a considerable number of road side Storage Tanks could be installed at a comparatively lower outlay.

Engines. An Internal Combustion Engine using Crude Oil Fuel would undoubtedly best serve for driving the Pump or Pumps. Such

Mr. E. F. White.

an Engine would occupy but little ground space, required a small building, had extremely low running costs, and would not require any boiler. Oil Engines were available in which the speed might be finely adjusted by the turn of a screw down to 50 per cent of the normal, whilst running. Therefore a variable speed gear would not be required. If less than 50 per cent. of the normal quantity of water was to be delivered from a Ram type Pump, the surplus might be automatically bye-passed through a pressure relief valve of spring loaded type, suitably adjusted for a predetermined pressure, from the delivery to the suction side of the Pump and economy in power used would result. If a Centrifugal Pump was used at half its designed speed it would probably deliver no water, so it would not need a bye-pass.

Stop Taps. As a Stop Tap would in any case be needed by each House, it might be designed also to serve as a check pipe. A cast iron cock having its brass taper plug drilled to the nearest 64th inch for passing the desired quantity of water was suggested. If a lug on the body of the cock be drilled to correspond with other holes in the square head of its plug, it would be possible to wire and lead seal the cock in either "on" or "off" positions.

The comparatively short water way through the plug of the cock would be less liable to reduce by corrosion the quantity of water passed, compared with the friction and reduced aperture likely to be caused in course of time by corrosion in a length of copper tube of small bore. The Cock Plugs could all be interchangeable and suitably marked for size of aperture. The Plugs could easily be removed by an Official authorised to break the seal for the purpose of cleaning and no filter would be required.

Mr. E. E. Desbruslais.

Mr. E. E. Desbruslais thought that there were two methods in which, the paper set out by the Author, could be considered.

(*a*) From the point of view of the Average householder.

(*b*) From an Engineering point of view.

(*a*) So far as was known from the methods in use in the water works of supply at Calcutta and Patna, the supply was obtained in the former case by pumping from a central reservoir in town, to the consumers residences and in the latter by gravitation from central tanks on towers and in cases of large consuming institutions such as hospitals from tanks on towers within the compound.

In the case of towns like Bhagalpore, Arrah and Serampore, the water supply was obtained by direct pumping from filter-beds and storage reservoirs near the pumping station.

Mr. E. E. Desbruslais.

An intermittent supply was almost always given, not so much as to prevent waste, as to deal with the demands at certain periods of the day when it was greatest and when not required the supply was stopped; and this in fact prevented waste to a very great extent.

The author stated that at Kalimpong, the meter reading method of charging had proved very satisfactory without any difficulties having arisen. Even in his statements, showing the neglect in fixing and reading meters, it was found that at Berhampore, Krishnagore and Utterpara, attention had been paid to the matter and of course the conclusion was that it had worked well, though no mention had been made as to this by the author.

The meters besides could be designed to be made so that the readings were visible to the householder and would not then surprise him, if he took the trouble to read them or watch them, as he was accustomed to do with his Electric Meter readings.

For street purposes, water was needed not only for people in the vicinity, but for animals for which public troughs and stand pipes were found as well as for public street latrines (in Calcutta) and for other sanitary arrangements as well as for fire prevention. As regards this last, the author stated that in practically none of the waterworks in Bengal had fire hydrants been fixed. In Calcutta, the hydrants used for street watering were used by the fire engines, the Pumping Engine working at night being connected to the fire alarm towers by Phone as far as possible direct.

This was as it was now in Calcutta.

The method proposed by the author had many disadvantages.

(1) The tank on the roof with its inspection, cleaning and leakage of ball valves all fell on the householder's shoulders.

(2) A guest or two for one day even, would cause a shortage of supply, and any influx of guests for a longer period would call for the erection of extra tanks, piping and especially the putting in of extra check pipes the sizes of which and arrangement could only be got at by trial and error.

(3) Having to dewater the remaining water in tanks, in places like large boarding Houses and hotels, due to the number of people in various seasons varying. This would be a large waste of water.

(4) A full supply calculated only on a certain percentage of the House value, might in case of a very wealthy bachelor, charge him excessively and cause an excessive wastage from disuse of the greater part of the water supplied.

Mr. E. E. Desbruslais.

(5) In the case of double storied buildings or higher and buildings of great length such as hotels and boarding houses, tanks on the roof above would not do as the lower stories would take off at a higher pressure and get more water than the upper stories mechanically and in the case of 2 stories 40 per cent. more water. In the case of long buildings owing to the head being only that of one storey, tanks would have to be distributed over the whole length to allow of equal supply.

In the case of direct pumping, the large pressure obviates these difficulties of tank decentralised methods.

(b) From an Engineer's point of view:

(1) It would appear that the pipes would always be under considerable pressure, and that the flow through the check pipes set in pitch or lead might cause them to bell-mouth whence wastage would occur. What about possible lead poisoning? What about the white sediment that encrusts all water supply pipes, choking such small pipes as the check pipes or reducing supplies?

(2) Putting tanks on roofs with masonry protection against heat, would require a structure, entirely independent of the roof, which for a tank of 150 gallons, would otherwise load the roof or floor with about 9 cwt. per sq. ft. extra.

The alternative idea would do, as it would cost less, but the upkeep, painting, etc., would be great and would all fall on the householder.

(3) The construction and fitting of suitable check pipes, with the tank say on the 3rd storey and at a considerable distance from these, by trial and error, would be a matter of considerable delay and expense.

(4) Any increase in the number of house connections in a zone would seem to require a change in the pressure reducing valves at that zone centre, and this would change the supply from check pipes already fixed. How about wastage?

(5) The author was strong on a continuous supply, but this scheme allowed only a supply of storage in 10 hours.

Now it was generally from 6 A.M. till noon that the demand was high and again from 3 P.M. till 6 P.M. in what was called the intermittent system, in which the supply met the demand during those periods. In the author's scheme, the early demand might exceed the supply for the early period, resulting in an excess for the later period to the great annoyance of all householders.

(6) Poorer people depending upon street supply, might have great difficulties owing to wastage of water from street tanks, in the author's scheme, and might in fact get none, as there was no check to wastage by the public.

Mr. E. E. Desbruslais.

With the present so called intermittent supply water could always be obtained twice a day and in any quantity which was a great boon.

The scheme of the author seemed, theoretically under certain conditions only, to be good but entirely in the favour of the suppliers.

There was no reason why meters should not be more used than at present in the intermittent scheme.

Dr. K. C. Chakko.

DR. K. C. CHAKKO remarked that he had often heard complaints that certain parts of the City of Madras were always short of water. This was due to the distance from the reservoir and consequent insufficiency of pressure when water was taken by the houses nearer to the reservoir. Yet, the system was designed so that when the maximum rate of flow took place, every district would get some water. This showed that it was not possible to design a system perfectly when the data were imperfect. The author's method of introducing check pipes to regulate the flow had therefore much to commend it, as it got over the imperfections of all hydraulic formulæ by adjusting the check pipes to the required rate of flow to each house which would be directly measured.

He would request the author, however, to consider the following points which had come up in his mind as affecting the system.

1. How far was it justifiable to assume that the rate of flow into a "district" was constant?

2. Was it possible to keep a uniform hydraulic gradient in the main pipes (a) when different districts draw water at different rates and (b) when the resistance of pipes altered with age?

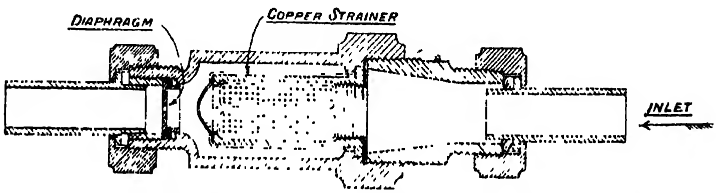
3. If valves were used in main pipes and chief distribution pipes in order to isolate certain districts, how would their closing, complete or partial, affect the supply to the houses?

4. Would the discharge through the Check pipes remain unaltered for the same head indefinitely? If it changed with time, would the "prolonged and difficult operation to make the alteration" to readjust the rate of flow be justifiable?

5. The flow from a partially closed tap was easier to regulate than from a check pipe. Was it not possible to enclose the tap effectively in a sealed or soldered box so that unauthorised people would not tamper with it? If this was possible, the check pipe was unnecessary.

6. Were not some meters still necessary, at least for the districts?

Mr. N. B. Wilson in forwarding a tracing remarked that the proposal was in his opinion, a better proposition than the check pipes which the author of the paper explained to the Members of the Society on Tuesday, the 15th instant. From the tracing it would be seen that instead of using a comparatively long length of small diameter pipe inside the service pipe, it was proposed to use a diaphragm having a small hole in the centre of it. From the construction of the apparatus, it would readily be seen that this diaphragm could be altered very easily. For instance, if it was found that the diaphragm used was passing more water than the consumer was entitled to receive a diaphragm having a smaller orifice could easily be inserted. In addition to this, the water passed through the copper strainer which would prevent any suspended matter from choking the small orifice in the diaphragm. Mr. N. B. Wilson.



PROPOSED ARRANGEMENT IN LIEU OF CHECK PIPES

Mr. J. O. A. Vincent remarked that the author in giving the alternatives for pumping installations rejected centrifugal pumps on the grounds of high horse-power consumption even though no water might be delivered by the pump. Mr. J. O. A Vincent.

With properly designed centrifugal pumps the characteristics were far from those stated. Against a closed delivery valve the H. P. consumption should be little more than 1/3 of full load H.P.

In practice however under Mr. Griffin's scheme he thought it was unlikely that the demand for water would fall to anything like zero. Probably the demand would vary between full output and 1/3 of full output during pumping hours and there should be no difficulty in obtaining centrifugal pumps to give the lower output with an actual H.P. consumption of about ½ full load H.P. or in other words the efficiency at 1/3 output would be about 66% of that at full load.

These figures were not at all unreasonable and when it was considered that during the same variation of load the head would vary by only about 15 per cent without any regulation or automatic devices whatever, he thought the centrifugal pump would be found to be highly suitable for the duty.

An additional advantage of centrifugal pumps was their smaller cost. A centrifugal pump might be purchased for roughly

Mr. J. O. A. Vincent.

about 60 per cent of the cost of a ram pump of equal quality and duty. The centrifugal pump required no special devices except an engine or motor to drive it and there was no danger of bursting the mains by negligent driving, whilst any form of ram pump required elaborate variable gears or other controlling apparatus as well as ample automatic relief valves to provide against accidents.

Finally, if electric power was available for driving the pumps the direct drive of centrifugal pumps allowed such a compact and simple unit and one so easy to handle, that the duties of the attendant would be reduced to a minimum.

He considered that the characteristics of centrifugal pumps were such as to make them much more easily applied to the special requirements of the scheme explained by the author than any of the alternatives and he thought that anyone contemplating such a scheme would be well advised to adopt this simple and economical form of pumping plant.

Mr. H. L. Tyson-Wolfe.

MR. H. L. TYSON-WOLFE thought that—Mr. F. C. Griffin should be congratulated upon the very interesting paper he had contributed to the Institution. The wasteful use of water presented a most difficult problem all over India, and the proposals put forward by Mr. Griffin seemed to him a very practical way of dealing with the difficulty.

Mr. Griffin's table disclosing the fate which attended the use of water meters was very significant, but it was noticeable that no reasons were adduced for the great prevalence of casualties. There were probably a number of reasons, but he felt that at least one of them was the inherent disabilities that beset all types of water meters of the rotating kind. Even where the water was filtered, wear in the rotating parts took place after a relatively short time; and where the water was at all silt bearing the wear was very rapid. As an accurate means of recording the amount of water passed, such meters were and probably always would be very unsatisfactory instruments.

In discussing the relative merits of different kinds of pumps Mr. Griffin said with reference to the centrifugal type that the full horse-power of the engine was absorbed although no water might be delivered by the pump. He thought that this view of the matter was somewhat overstated. It was a matter of experience that there was a very appreciable difference in the amount of power absorbed by the pump when it was delivering its full output and when it was simply churning the water in its casing when the delivery valve was completely closed. That this was so could readily be ascertained by observation; but the view expressed by

Mr. Griffin had been put forward again and again. If 100,000 gallons of water were pumped at a steady rate over 8 hours, against a head of 60 feet, the foot pounds per minute were sufficient to raise the temperature of a pound of water from 60 Fahrenheit degrees to 220 degrees in one minute. If what the Author said was correct, the pump would become dangerously hot in a very short space of time, were it to be run with its delivery valve closed. Such a pump might be, however, and often was run for quite an appreciable length of time with the valve closed, without much rise of temperature becoming noticeable. Mr. H. L. Tyson-Wolf

From the particulars given in Plate III it was seen that the pressure at the pump is 60 feet water column, and that at the elevated tank was 25 feet. If the tank was taken to be say 4 feet deep, the average pressure at the tank was 23 feet water column. It was seen, therefore, that the efficiency of the transmission was only about 38.5 per cent. As this was a very low figure it would be interesting to have the author's opinion about this. He would like to know how this result compared with the results usually obtained in the ordinary system of water supply with which one was familiar; so low an efficiency would appear to entail unduly great expenditure on power.

There was one other matter on which he would like to offer comment; namely to the use of a ball valve on the top of the service tank. It was probable that in many cases this would be tied up and thrown thereby out of action. Such a proceeding would enable a householder to obtain more water than his proper share in such cases where the rate of flow through his check pipe was rather on the liberal side than the reverse.

Mr. S. P. Flowerdew remarked that he had Water Supply Problems in many railway Colonies and expressed his intention of taking an early opportunity of introducing Mr. Griffin's System in some of the railway Colonies on the E. I. Rly. Mr. S. P. Flowerdew.

Mr. Mahan Dev congratulated the author on devising a scheme which would not only produce an income sufficient for the maintenance of the scheme, but would at the same time impose a check upon waste. Mr. Maha Dev.

His objections to the centralised method of distributing water from one main reservoir were the expense involved in laying duplicate mains, or alternatively the risk of failure if duplicate mains were not laid and there were difficulties in connection with control of supplies, repairs to main and cleaning of pipes.

·. Mahan With regard to the author's schemes he considered that the following points might be a drawback:—

1. The weight of the tank might be too much for the roof to carry.

2. The first cost might be too heavy for the poorer classes.

3. Space would be occupied which might be more usefully employed in congested cities.

4. The extra expense of protecting the tanks from the Sun.

5 & 6. Deteriorations of the check pipes through corrosion or incrustation.

7. The necessity for frequent repairs.

With regard to the pumping machinery he was of opinion that electrically driven pumps offered many advantages over pumps driven by an oil engine on the score of lesser first cost, lesser maintenance charges, cheaper buildings and greater cleanliness.

With reference to rule 7, he very much doubted whether the occupiers would pay sufficient attention to the cleanliness of the overhead tanks and feared that this would eventually devolve on the municipal authorities.

he Author. THE AUTHOR in reply remarked that, in the first paragraph of his note, Mr. Williams stated the facts with regard to water supply schemes, and the present inefficiency and wastage in the metering system. It was because these facts had not been fully taken into consideration that the present difficulties in water supply had arisen.

Mr. Williams stated that the system proposed in the paper would be less popular than the old system. This remained to be seen. The fact that two municipalities had already willingly adopted the system did not support the statement. In the last sentence of the first paragraph, Mr. Williams said,—"If however the supply was actually restricted to a definite daily quantity, that was an end of it, and however great his real or imaginary need, he could get no more". This was not so. He might draw Mr. Williams' attention to the para marked (c) on page 14 of the paper. When the householder had come to the conclusion that he must have more water, he would go to the municipal authorities to find out how it could be obtained. He would be informed that if he paid a bigger water rate he would be given more water, and this would appeal to the ordinary man as a straightforward bargain. He would decide on the additional amount which he required, would sign the agreement to pay

the corresponding tax, and forthwith the check pipes would be altered to give the increased amount. Of course the householder might attempt to get the increased amount of water by unfair means. He might attempt to bribe the waterworks staff to come and alter his check pipes without having prearranged to pay the additional tax. But there were a number of factors which would automatically nullify such attempts at bribery. First, the number of people he would have to bribe,—the whole waterworks staff plus coolies, cartmen, and others engaged on the job, would make the process of bribery so expensive as to be scarcely worth while. Secondly,—since the operation of changing the check pipes was a day's work, involving the digging of a trench, disconnection and refixing of a pipe line, etc., the job could not be done surreptitiously but must be carried out in broad daylight. It was therefore sure to be seen and recognised by someone as a house connection job,—enquiries would be made,—particularly by the householders' enemies,—and if all was not fair and square the culprit would be shewn up. Mr. Williams went on to refer to the outcry on the part of the gentlemen who found their cisterns empty when their neighbours' were still full. Let us imagine such an objection,—taking place at say a meeting of the local Ratepayers' Association. Mr. A complains that his tank was always empty and that the supply was not enough for his family which was a big one. Mr. B sitting alongside him had plenty of water,—there were only 3 other people in the house beside himself and his allowance according to his rated water payment was ample. Mr. B will say to Mr. A,—"all right,—nobody is stopping you from getting more water,—if you want more, *pay for it*". The Author

The position was perfectly clear and simple. Generally speaking, people did not expect to be called upon to give either goods or service without being paid for them, and conversely, they did not expect to get anything without paying for it. For an increased allowance of water therefore they would expect to pay, and would be quite content to pay. The mischief of the present system was that householders were not called upon to pay until long after the goods were received, and did not know even whether they would be expected to pay or not. Also they were aware of the easy methods by which they could evade payment, as Mr. Williams pointed out in his note.

With regard to the "engineering difficulties" which Mr. Williams mentioned.

(1) "Adjustments of rate of flow to a most complicated variety of conditions of pressure and quantity". The check pipes would be different for every house, but he saw no difficulty in fixing them.

The Author After a little experience the number required would be guessed very approximately, and then the exact number would be settled by trial and error,—the rate of rise of water in the tank would be the measure of the flow.

(2) "It depended on the accurate working of a number of reducing valves". The makers told him that with a secondary pressure of 40 feet the variation of pressure would not be more than 0.6 of a foot. In any case it should be noticed that the variations of pressure would be sometimes plus and sometimes minus. So that during the day the variations would average out, and the daily quantity of water discharged to the roof tanks would be constant.

(3) A reference was made to "minute apertures". The smallest check pipe likely to be required was 1/8″. He did not think this should be called a "minute aperture".

(4) "It presupposes conditions that did not exist in any Bengal waterworks". He did not propose at present to apply the new system to an existing waterworks. It would be applied at first to new waterworks.—in which, of course, the conditions would be arranged to fit the system. The application to an existing waterworks would be a more difficult business, involving points of law with regard to old house connections, etc.

(5) "Any appreciable alteration in the pressure would operate inequitably upon neighbouring houses". His proposal was that there should *not* be appreciable alteration in pressure,—hence the use of the latest type of reducing valve,—the large sized zone mains,—the *average* flow through them instead of the *maximum*, etc., etc.

Mr. Williams summed up his criticisms by saying that he could only come to the conclusion that his proposals were quite impracticable and unworkable. To this his only reply was that other engineers had already expressed the exactly opposite view, and that he of course agreed with the latter.

Mr. Williams went on to say that the only really satisfactory course in regard to mofussil water supply was to confine the supply to street standposts only. But this was begging the question. In a good many of the water supply schemes now under consideration the Municipal Commissioners refused to have a scheme at all unless they could have house connections. The problem before us was how to provide a water supply *with* house connections and yet to prevent the wastage of water. The last page of Mr. Williams' note was therefore beside the point.

The Author.

In reply to Mr. Ramalinga Aiyar, who began by stating the present position with regard to waterworks, he agreed with his suggestion that if water were charged for by meter alone, as with electric supply, all would be well. But, as explained in the first paragraph of his paper, the majority of the people must draw their water from street taps, and it was impossible to meter and charge for the water they take.

With regard to Mr. Aiyar's objections to his scheme.

(1) The first was that the check pipes could not be satisfactorily determined and fixed in practice. He did not think there would be any real difficulty in this, it would be done as described at the bottom of page 9 of the paper. The Zone mains would be big enough to obviate any appreciable variation in pressure which might otherwise be caused by the opening and closing of connections. Of course, when more connections were made than the number for which a zone was designed, there would then be a drop in pressure. This contingency was dealt with on page 16 of the paper.

(2) The reason of the statement,—"the ends of the copper tubes should not be bell-mouthed,"—was asked for. If the tubes were bell-mouthed, there would then be *gradual* contractions and expansions in the size of the pipe. When there was a *sudden* change of diameter, loss of head occurred. The object of the check pipes and little chambers between was to reduce the head (thereby checking the flow), consequently the sudden change of diameter was required. These little chambers between the ends of check pipes would act as a "fine adjustment". They need not necessarily be inserted,—the check pipes could be coupled by a single socket. The addition of the double socket and nipple connection increased the amount of check to a small extent, as could be seen by a comparison of tests Nos. 2 and 3, page 10 of the paper.

(3) "The introduction of independent service tanks was a retrograde measure". He did not agree. His arguments were given in the last para but one on page 11. Calcutta had during the last 10 or 20 years been forced into this system. The water need not deteriorate in a roof tank which was covered and locked, which was protected from the sun, and of which the householder took reasonable care as provided in rule 7, (page 18).

(4) Admittedly, the fire hydrants would be of no use at night until the waterworks could be started up. But as pointed out on page 12, no mofussil municipality provided for fire appliances. And in the case of a town big and important enough to go in for a fire brigade, the probabilities were that at least 16 hours, if not 24 hours per day, would be the pumping hours.

The Author. (5) The figures given in rule 9. These were of course only approximate and typical,—each municipality would have to work out its own schedule of rates, and obtain Government sanction to the same.

In reply to Mr. Temple's comments.

(1) He was glad to note that he approved of the suggestion with regard to "check-pipes". Samples of these were placed on the table at the meeting.

(2) The arrangement for taking water from the storage tank at different levels was a good one. He had however suggested two separate storage tanks in the case of houses with sanitary fittings in order to meet a religious objection. Orthodox Hindus would, he was told, refuse to take drinking water from a tap which they knew had direct connection with pipes feeding a W. C. flushing tank.

(3) The Rotary Bailer was an excellent waste preventer, but would not do as a substitute for the street tanks in his scheme. In the Rotary Bailer a practically constant water level was maintained by means of a ball valve. In his scheme the tank must be capable of filling and emptying, the ball valve being used only to turn off the water when the tank was full.

Mr. R. M. Gupta had suggested that the system was likely to cause inconvenience to the consumer, that depended on what was meant by "inconvenience". If the consumer would be inconvenienced by the discovery that his supply of water was not unlimited, and that he had not enough water to throw about and waste, then he certainly would be "inconvenienced". If, on the other hand, he used the water economically, there would be no inconvenience on the score of quantity of water available, and he would have been given a great additional convenience in the shape of continuous house supply.

To enforce economy in the use of water was the whole object of the system.

(2) The storage tank on the roof would meet the difficulty of variation in demand. In the case Mr. Gupta mentioned, the man having had his bath in the morning, and having used the water economically during the day, the tank would *not* be almost empty at night,—since it had been filling slowly all day long, and so there would be plenty of water for his bath the next morning. If on the other hand, he took two or three baths during the day, leaving the taps running, and generally wasted the water, then the next morning he certainly would find the tank empty, and would have to wait a long time to get his bath. That was exactly what was intended. The effect would be that during the following day he would

have less baths and would stop the waste of water,—precisely the effect desired. He had not suggested additional storage to meet the extravagant use of water,—sufficient storage was required solely to meet the variation in demand. The ball cock was not meant to prevent the waste in the house,—it was simply to prevent the tank overflowing. The Author

(3) *His third paragraph.* In this system, pumping doubtless would be commenced in the early hours of the morning.

(4) *His fourth paragraph.* If there was any "aversion" to using water which had been standing in a covered roof tank overnight, people would soon get over it. On sanitary grounds there could be no objection.

(5) *His fifth paragraph.* The two sentences were contradictory. If there was no objection to designing the mains to deliver the average rate, then there could be no use in designing them at twice the average rate. He might draw Mr. Gupta's attention to page 8 of the paper.

(6) *As regards the point (1).* He thought the fixing of check pipes would be quite simple after a little experience had been gained.

The point (2). This was quite true. When that time arrived, the difficulty could be met either by pumping somewhat longer hours, or by increasing the pressure, or by reducing the check pipes.

The point (3). The statement was quite true. Attention was drawn to page 16 of the paper.

(7) *The two paras with regard to water allowance.* The statement was made that, "there was no reason why the poor man—should not be supplied with the same quantity of water as the rich." This was a remarkable statement. It was of course understood that he was talking about pumped and filtered water, delivered in a man's house,—not the water flowing by in a river or lying in a tank. Whereas the latter water was free and for all, the former water was a thing which cost money—which could only be provided by the work of certain other persons and by the expenditure of capital and maintenance costs. Surely it was obvious then that such water must be paid for, just as with food or clothing, and also that the quantity supplied must be according to the money paid, just as with food or clothing. There was no question of depriving the poor man of the drinking water necessary to sustain his life. He would always be able to draw water from the street tanks, and the amount required for drinking was very small compared with the total *per capita* supply.

The Author. (8) *The last para but one.* "The other method of preventing waste was by increasing the supply". The reverse was obviously the case,—an increase in supply without altering the present system of house connections would simply increase the waste.

(9) *The last para.* The paper revealed the fact that metering had not been successful, and that care was not taken that meters were in working order and regularly read. Hence the suggestion of another system.

He was much obliged to Mr. White for drawing attention to two points in which the paper was incorrect.

The first was that with the most modern types of oil engines the speed could be adjusted down to 50% of the normal while running, instead of 10% as stated in his paper; and the second that with a centrifugal pump running against the pressure of a closed main, only 30% of the H. P. of the engine was being absorbed, and not the full H. P.

Both these points meant that his scheme was even more easy of application, and no speed gears would be required.

The spring loaded pressure relief valve should always be fixed as a safeguard against sudden accidental closing of a delivery sluice valve, or other mistake. It should not however be used as a means for controlling the quantity of water delivered, since water by passing through it had been pumped against the full head, and the full horse-power of the engine was therefore being absorbed although less water was being delivered.

The specially designed stop valve with orifice, and the key operated regulating valve were already on the market. But it was not proposed to use these for the reason explained in the sentence in the middle of page 9 of the paper.

Mr. Desbruslais had mentioned several disadvantages, in replying he would say :—

(1) The tank on the roof was in substitution for the chowbatcha. The householder had to clean and maintain the latter, and therefore it would be no hardship to have to clean and maintain a tank. Also, in Calcutta, a large number of houses already had tanks, and there was no complaint in the matter.

(2) The supply would be sufficient as a rule for a "guest or two". If it was not, there was always the street tap from which extra water could be drawn. For the larger number of guests, the temporary connection was provided. This was not a "disadvantage." Extra water could be obtained for extra payment. There was no trouble to the householder. He simply paid, and the waterworks staff did the rest.

The Author

(3) There was no waste of water in dewatering a tank. To empty a tank, simply shut the inlet valve, and wait until the water consumption emptied it.

(4) The reference to the wealthy bachelor was not understood. The wealthy bachelor was likely to have more water for his use than the poor man with a big family. That was in the natural order of things. Presumably however the Municipality could pass a special order, to "tax the bachelors" if it so wished!

(5) The idea was incorrect. It is true of course that there was a greater pressure at the lower storey than in the upper, but by a proper arrangement of pipes and taps, every point in a building could get similar quantities of water from a central storage tank. The pipes to the upper storey would be larger than those to the lower storey, to compensate for the smaller pressure.

The Engineering Points :—

(1) The reference to bell-mouth and wastage was not understood, he preferred that pitch should be used in the check pipes. In the course of time, the check pipes as well as the rest of the mains were liable to become encrusted. This was a difficulty common to all forms of waterworks, and various methods were used for dealing with it. At the present time, at a small waterworks at Chand pur, the whole of the pipes were being taken out, cleaned, and relaid.

(2) As can be seen from the drawing, the suggestion was that the weight of the tank should be carried on the walls and not on the roof. The weight of the asbestos sheeting cover was very small.

(3) He did not think the fixing of check pipes would be very difficult.

(4) The pressure reducing valve was automatic, and adjusted itself to give more or less water as required, and to maintain a constant pressure.

(5) The remark "A supply of storage in 10 hours" was not intelligible. Water would flow into the tank for 10 hours, and was stored there. If the outlet taps were kept properly shut when the water was not required, the water would accumulate in the tank, and there would be a good quantity stored ready for the time when it was required.

(6) There was likely to be a very effective check to wastage by the public from the street tanks. The people who habitually drew water from a particular tank would very soon see to it that the taps were properly shut.

The Author. The points which Dr. Chakko mentioned.

(1) The rate of flow into a district was not to be kept constant. It was the head which was to be kept constant (or practically so).

(2) (a) It was not necessary to keep a uniform hydraulic gradient in the main pipes (trunk mains). All that was required was that, at times of maximum flow, the gradient should be such that the pressure just before the reducing valve was above (how much above does not matter) that fixed for the zone.

(2) (b) The resistance of the mains,—when steel or cast iron was used, would increase with age. His replies to the comments of other members might be seen.

(3) If a valve at the beginning of a main was closed, it would stop the supply to the houses on that main. If partially closed it would check the supply and cause a drop in pressure, the result being that the flow would cease, first in the highest houses, and later in the lower ones.

(4) With a pure water, the discharge through the check pipes would remain constant for a long time. The "prolonged and difficult operation" was only half a day's work or less,—it was prolonged and difficult compared with the operation of opening a surface box and turning a tap, which could be done in a few seconds.

(5) Whether a tap in a "sealed or soldered box" would escape being tampered with was a matter for experiment. Opinions differed as to whether it would be effective or not. He had suggested the check pipe as a simple, cheap, and effective method of geting over the difficulty. The check pipes would, he thought, be cheaper than a special tap with a special sealed box.

It would be easy to regulate the flow with the check pipes.

(6) Meters for each district would be useful in such a distribution system, though not essential. A meter at the pumping station was in his opinion absolutely necessary. A more necessary thing for each district would be a Bristol Automatic Pressure Recorder.

The drawing sent with Mr. Wilson's comment shewed a design which would probably be useful in place of check pipes in certain cases. The design was similar to figure E46 of Messrs. Glenfield & Kennedy's catalogue, and he had considered it before. His chief reason for rejecting it was the feature which Mr. Wilson seemed to put forward as its advantage,—that described in one of his sentences,—"From the construction of the apparatus, it would readily be seen that this diaphragm could be altered very easily." His object was to produce a regulator which could not be altered

very easily. The last para. but one on page 10 of the paper might be seen. The Author.

He also thought that the E46 regulator would be more expensive than check pipes. It might perhaps be cheaper than check pipes plus the strainer which he had shewn on plate IV, but he very much doubted whether the strainer would be necessary in ordinary circumstances with a good filtered water. The orifice in the diaphragm of the E46 design must obviously be much smaller than the diameter of his check pipes, and it was essential that the orifice should be protected by a strainer. But as the smallest check pipe was not likely to be less than 1/8″, a strainer to protect the check pipe would in all probability be unnecessary.

He agreed with Mr. Vincent that the centrifugal pump was eminently suitable for pumping in the type of scheme illustrated in the paper.

He agreed with Mr. Tyson-Wolfe in his remarks with regard to meters. For their proper maintenance considerable expenditure was necessary. In meter maintenance in Bengal a difficulty was encountered in the fact that the meter was installed by, and belonged to, the householder, and yet the maintenance of it had to be done by the municipality. It was in the interest of the householders that meters should go out of order, and although it was to the municipal interest that they should be kept in order, the forces operating towards good meter maintenance were not sufficiently strong.

The statement in his paper to the effect that the full H. P. of the engine was absorbed although no water might be delivered by the pump was incorrect. As noted in replies to other comments, the H. P. absorbed should be only about 1/3rd of the full load H. P.

With regard to the efficiency of the distribution system, he might point out that with the old method of design the efficiency of the transmission was even less. It had been the practice in his office to design the system with a terminal head of 10 ft., and an initial head, (in a flat town) of about 50 feet :—giving an efficiency of only 20 per cent. The design of a distribution system was of course a matter of striking a balance between the cost of fuel for pumping and the interest on the capital cost of the pipes.

With regard to the ball valve of the service tank, it was of course possible that this would be tied open. But he did not see how that would enable the householder to obtain more than his proper share of water. He would gain nothing thereby,—the

The Author. result would simply be that water would flow out of the overflow pipe and would be wasted. The check pipes would limit the daily quantity of water to approximately the agreed amount, so that the waterworks was not overtaxed. The overflow pipe was dealt with in rule 8, page 18 of the paper.

Mr. Mahan Dev had mentioned several drawbacks:—

(1) Weight of tanks might be too much for the roofs. He would draw Mr. Dev's attention to the first para on page 12 of the paper. If the walls would not carry the weight, the tank might be placed on a brick or iron pedestal in the compound.

(2) He drew attention to the explanation of rules 6, 7 and 8, on page 13 of the paper. Cost would be no more than that of the present system. The point was referred to again towards the end of the comments. Since the total cost of a house connection would be no more than that in the present system, the public would not object to it.

(3) Attention to 2nd para on page 12. When a street was too narrow for a road-side tank, the tank would be placed at the end or on the nearest available space.

(4) Cost of sun protection was included in item (2), see page 14

(5) & (6) Check pipes might widen out or become less in course of time. He thought it would be a considerable time. Water works appliances of every kind required occasional attention and rectification.

Mr. Dev had pointed out the advantages of the electrically driven pump over that driven by an oil engine, he seemed to over look the two all-important points, *viz.*, that in many cases electric power was not available, and also that when it was available the cost per unit was so high as to make electric pumping prohibitive.

Mr. Dev remarked at the end that the occupiers would not care to pay attention to the cleaning of the tanks. Since the tank belonged to the householder, and since the ill effects of the dirty tank would fall upon him and his household only, he thought he would keep it clean. If he did not, his negligence would not affect other people or the water supply as a whole.

SOME WATER TOWERS IN INDIA.

BY

F. C. TEMPLE, Member.

This is a brief account of 10 water towers constructed during the last 10 years varying in size from a little tank containing 800 gallons with its floor some 12 ft. above ground level, to one containing 111,000 gallons with its floor 83 ft. above ground level, and another of two tanks each containing quarter of a million gallons one at ground level and the other 35 ft. above it, and of two designed in accordance with instructions but as so often happens in India postponed indefinitely for want of money.

PURI LEPER COLONY. *(Plate 1.)* An octagonal tank 8′ diameter 2′—6″ deep on a tower 12 ft. high.

The walls of the tower are of laterite 15″ thick. The floor of the tank is a slab of concrete 6″ thick reinforced with No. 62 expanded metal. Round the outside of the tower at the level of the floor slab is a band of cement plaster. Overflows are through brass gratings over concrete spouts. At the top of the tank walls is a reinforced concrete chajja or sunshade. The roof is a dome of brick work, the first eight courses being built in cement with two $\frac{1}{4}$″ mild steel hoop tension rods. The lantern is made of timber and wire mesh. The top is hinged, so as to provide means of access for cleaning the tank. In the chamber below is a Challenge Force pump which draws water from a well just outside and delivers it into the tank. The supply is drawn from the rising pipe and delivered through four self closing taps placed round the outside of the tower.

PURI CHOLERA HOSPITAL. *(Plate 2.)* A circular tank 13′-8″ diameter, 5′ 6″ deep on an octagonal tower 12 ft. high.

The architectural features of the tower were designed by the Government Architect Mr. J. F. Munnings. The walls of the tower are of laterite blocks. The floor of the tank is of reinforced concrete. The reinforcement is $\frac{5}{8}$″ rods, 6″ apart at right angles to one another at the bottom and radial rods at the top. The walls of the tank are of masonry with a reinforced concrete core in which are set the steel tension rods to resist the water pressure. The roof is a light dome on a steel frame work the panels of which are

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filled in with 3″ thick concrete reinforced with diamond mesh. Access is given by a 2′ sq. manhole set in the dome. Ventilation is given through gauze covered openings all round a lantern. The inlet pipe which is controlled by a ball valve is brought up the out-side of the tower. The outlet is taken out of the centre of the floor.

MUZAFFARPUR HEAD WORKS RESERVOIR. *(Plate 3.)* The pumps at the Mazaffarpur waterworks deliver into three elevated reservoirs, from which the distribution pipes are fed. One of these is situated at the Head Works. It consists of a circular tank 23′ diameter containing 24,000 gallons with 10′ depth of water and floor 30′ above ground. It is carried on an octagonal brick tower and a central shaft which is carried through the water space to give access. The weight on the brick work is limited to 3 tons per square foot. The tower stands on a reinforced concrete block spreading the load to ½ ton per sq. ft. on the soil. The floor of the reservoir is of 5″ brick set in cement. Half bricks and random bats were used, set on end. In the joints are ¼″ steel rods, forming a grid at right angles of rods 5″ apart in one direction and 3″ apart in the other. Over the 5″ of brickwork is 6″ of cement concrete.

The reservoir is a true balancing reservoir. There is only one pipe for inlet and outlet : when the supply from the pumps exceeds the demand the excess water accumulates in the reservoir : when it is less the deficiency is made good from the reservoir. The single pipe is brought through the floor and finished in a bell mouth on the floor level. Overflow is by a 4″ pipe also taken through the floor. Where the pipes go through, the reinforcement of the floor is secured to a steel ring, and the floor is strengthened by the addition of a reinforced brick beam, extending from the outer wall to the central shaft. The junction of the pipes with the floor is rendered watertight and given pliancy to allow for inevitable movements by a collar of soft bitumen.

The walls of the tank are of cement brickwork forming an inner and outer lining enclosing a cement core reinforced with Expanded Metal.

The roof is a two ring brick dome set in cement. The tensile strain in the lower part of the dome is taken by steel wire set in each course of the brickwork.

Ventilation is through wire gauze covered openings in a lantern on the dome. These openings are arranged to give access to the outside of the dome.

Control valves are placed in the bottom of the tower and there is a bye pass for pumping direct into the mains when the reservoir is being repaired.

A water tower almost exactly similar to this in the superstructure and tank has been built at the Indian Iron and Steel Works, Asansol.

MUZAFFARPUR SOUTHERN RESERVOIR. *(Plate 4.)* This contains 70,000 gallons and like No. 3 is a true balancing reservoir. The tank is 39′ diameter holding 10′ depth of water, and rests on two concentric brick towers, the inner one of which is carried right up to the roof. Weight on brickwork is limited to 3 tons per sq. ft. The tower rests on a reinforced concrete block giving a load of $\frac{1}{2}$ ton per sq ft. on the soil. The floor of the reservoir is carried on the two annular brick towers and on reinforced brick beams set between the inner and outer towers. The construction of the floor of the tank and the arrangement of the combined inlet and outlet pipe and of the overlow pipe, and the construction of the walls is the same as in No. 3. Access is provided by means of a ladder to a landing in the inner tower and thence by another ladder through a shaft in the centre of thhe tank.

The roof is a very light dome shaped structure resting on the inner tower at the centre and on the outer walls. It is $2\frac{1}{4}''$ thick reinforced concrete made by fixing wire mesh on a light steel frame work and as the engineer in charge said "throwing cement plaster at it."

Ventilation and access to the outside is provided by wire gauze covered openings in a lantern.

MUZAFFARPUR NORTHERN RESERVOIR. *(Plate 5.)* This is a balancing reservoir similar to Nos. 3 and 4 but holding 100,000 gallons.

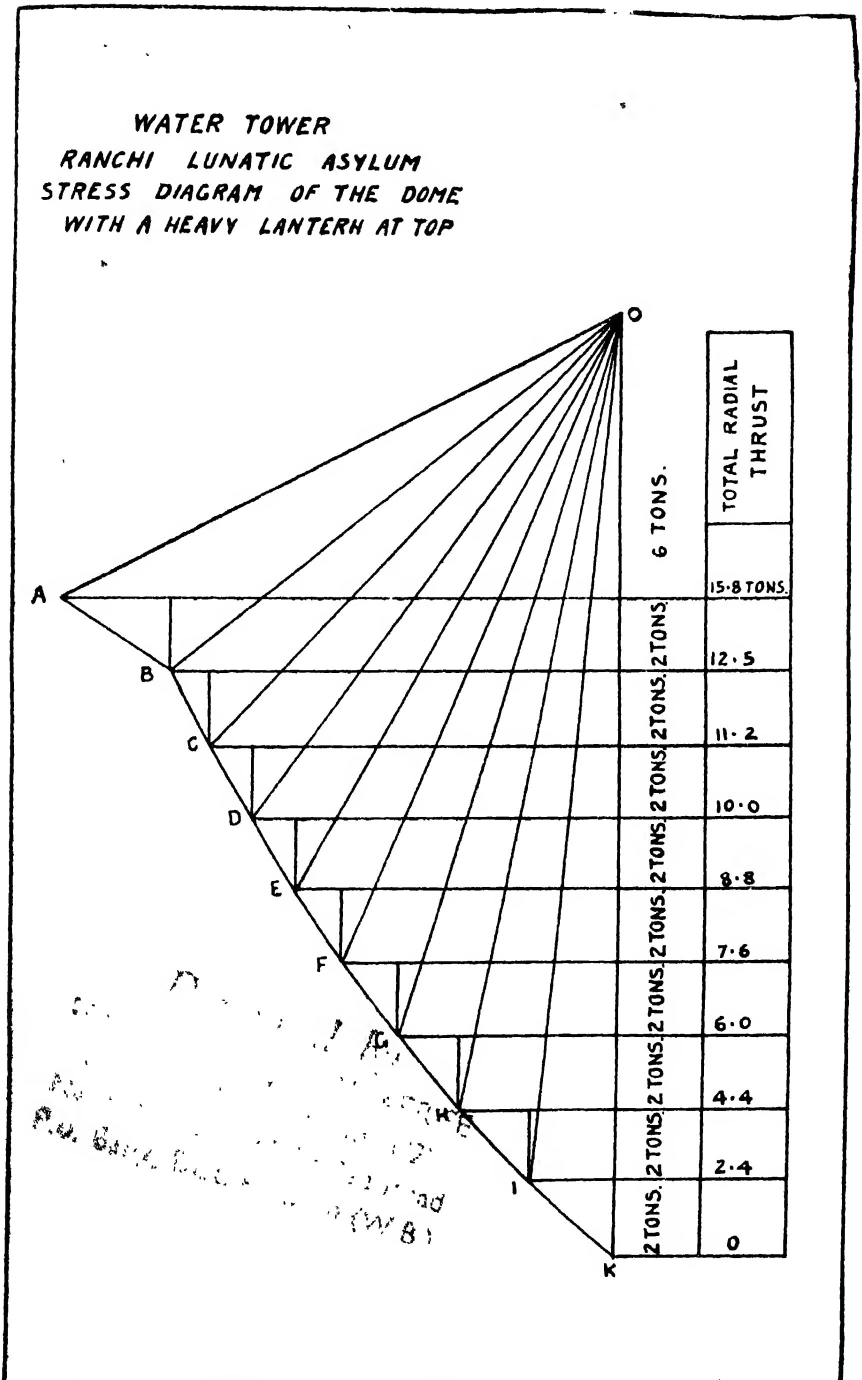
The design and construction are similar to that of No. 4 except that as the diameter of the tank is 47′ the roof is built almost flat. The outward thrust due to the slope of the roof is taken up by a steel ring set in concrete.

In No. 3, 4 and 5 provision for the inevitable movement at the junction of wall and floor of the tank is made by taking the reinforced core of the wall down to the underside of the tank floor.

PATNA GENERAL HOSPITAL RESERVOIR. *(Plate 6.)* This consists of a circular tank containing about 25,000 gallons, 20′ diameter with a dished spherical bottom of 15′ radius. The dished spherical bottom rests on an annular brick tower some 35′ high.

The dished spherical bottom is constructed in reinforced concrete designed on the principles laid down for steel tanks by the late G. F. Deacon, M.I.C.E. based on the fact that the tensile stress at any point is $\frac{rp}{2}$ where r is the radius and p the pressure per unit area. The reinforcement is arranged in concentric rings and radial lines so placed that in every area there is sufficient steel to take the tensile strain. As the radial rods go apart and are too far separated to take the stress others are introduced in the intermediate spaces. The stress of the whole bottom is secured on the walls by a reinforced concrete ring into which the radial rods are bent over. The walls are built as in No. 3, 4 and 5 of two rings of brick enclosing a reinforced concrete core. In this form of construction there should be no separate movement of walls and floor. The roof is of 3″ reinforced brick panels, 3″ thick on a frame work of $1\frac{1}{2} \times 1\frac{1}{2} \times 3/16$ T iron. Ventilation is provided by a lantern at the top. A ladder outside the tower leading to a manhole in the roof from which reinforced concrete steps lead down to the dished bottom gives access to the tank. The inlet and outlet pipe are one almost up to the floor but as the top water level is below that of the Patna elevated reservoir, the pipe is divided to give inlet through a ball valve at the top and outlet through a non- return valve at the bottom.

RANCHI LUNATIC ASYLUM RESERVOIR. *(Plate 7.)* This is a balancing tower of 50,000 gallons capacity very similar to No. 6 in design except that on account of the commanding position that it occupies on top of a hill much attention was paid to its architectural features, and a balcony was added from which the view of the surrounding country can be seen. The tank is 30 ft. diameter with a spherical dished bottom of 21′ radius, the depth of water being 10′ at the walls. The tank is carried on a masonry tower 34′ high. This tower has a base of rough dressed stone, and above is of brick with stone quoins. The bottom of the tank is constructed in the same way as that of No. 6 except that the radial rods are projected out to form the cantilever floor of the balcony. The rods are $\frac{3}{4}$″ rounds spaced concentrically and radially at 6″ intervals, and on them is laid wire mesh. The walls are similar to those in No. 6 the core being reinforced with X.P.M. and rods. The balcony has a roof which shades the sides of the tank and helps to keep the water cool. This roof is of light reinforced concrete tied to the wall of the tank and resting on reinforced concrete pillars standing on the cantilever floor of balcony. The roof of the tank is of reinforced concrete on a light angle iron frame The lantern which provides light and ventilation is sufficiently heavy to put the whole of the dome in tension. (See Stress diagram.) Access to the


WATER TOWER
RANCHI LUNATIC ASYLUM
STRESS DIAGRAM OF THE DOME
WITH A HEAVY LANTERN AT TOP
O
A
B
C
D
E
F
G
H
I
K
6 TONS.
2 TONS.
TOTAL RADIAL THRUST
15·8 TONS.
12·5
11·2
10·0
8·8
7·6
6·0
4·4
2·4
0

balcony and to the tank is provided by a turret staircase. The combined inlet and outlet pipe is brought up direct to and through the bottom of the spherical dished bottom. The valve gear is similar to that in Nos. 3, 4 and 5.

The spherical dished bottom built in concrete is not entirely satisfactory. The concrete is all in tension and sweats nearly always. If the reservoir is empty the concrete contracts slightly as it dries and the sweating is thereby increased. When it becomes wet again it swells and partly at any rate "takes up." The architectural features of this tower were designed by Mr. J. F. Munnings, Govt. Architect. The total weight of the tower when full of water is about 440 tons. The load on the brickwork does not exceed 3 tons per sq. ft. and that on the foundation ½ ton per sq. ft.

PATNA NEW CAPITAL RESERVOIR. *(Plate 8.)* This reservoir had a chequered history. Mr. G. W. Disney proposed to erect a steel tank to hold 100,000 gallons on a lattice frame work some 50′ high. Mr. J. F. Munnings persuaded him to put it on a masonry tower and clothe it in masonry with a domed roof. Mr. N. McK. Barron who came as Mr. Disney's assistant persuaded Mr. Disney to raise the level of the floor of the tank to 85′ above ground, but meanwhile the P.W.D. had begun construction. By the time the author took charge the tower was some 30′ high. Owing presumably to the divided responsibility no opening except the door with a portico intended for access had been left by which the water could go in or out.

The design of the tank was then changed from steel to reinforced concrete, and the capacity was raised to 118,000 gallons. It is 43′ internal diameter and contains 12′-9″ of water. It is built of reinforced concrete throughout. It rests on a circular brick tower and on two brick cross walls which divide the tower under the tank into three compartments. 15″×5″ Cross girders run between the cross walls and the circular outside wall.

The centering for the floor was made of planks supported on the lower flanges of the girders. At the floor level the outside wall is corbelled out to form a balcony. This gave sufficient space with the help of extra staging on the scaffolding for mixing the concrete at the floor level. The materials were all hoisted up in advance. Concreting of the 6″ floor was started at 7 A.M. Labour was provided in reliefs, so that from start to finish work proceeded on a green face avoiding the formation of construction joints and finished at 10-30 P.M. The reinforcement was X.P.M. laid one inch above centering, with strips near the top over the beams to take the reverse bending moment. The 12″ combined inlet and outlet pipe

finishes in a bell mouth level with the floor. The overflow is a 12″ bell mouth leading into a 4″ pipe. Where both these pipes pass through the floor they are fitted with a flange round which is a collar of soft bitumen to stop leakage. To prevent damage to the floor from movements in such high stacks the 12″ supply pipe is fitted with a stuffing box expansion piece, and the 4″ overflow is given an S bend cast off.

The walls of the tank are of concrete 9″ thick reinforced with X.P.M. The centering for the walls was made of 9″ brickwork in mud. This did not give a good surface and a ½″ cement rendering was necessary.

The roof is a dome made of panels of reinforced brickwork 3″ thick supported on an angle framework, the whole being surmounted by a lantern of concrete reinforced with steel rods. Access to the balcony is obtained by a reinforced brick staircase which goes up to a landing inside the tower leading out into a small balcony from which a ladder leads up to the main balcony. From the landing a reinforced brick walkway hung from the girders of the floor leads to the expansion joint in the stack of the 12″ supply pipe, and a spiral staircase leads up through the water to the inside of the dome. Thence iron ladders lead down into the tank and up into the lantern.

When the tank was first fitted there were some bad sweatings in the floor and some definite leaks in the walls particularly in that of the spiral staircase. These were stopped with ironite and with Matex.

The supply pipe entering the base of the tower from the pumps is 15″. It leads up into the tower through the 12″ stack already described and delivers to the town through a 14″, and two 8″ pipes. The two latter are fed through a Deacon waste detecting meter. There are control valves on each main and a byepass makes it possible to supply the town without going into the tank.

The sub-soil at the site of the reservoir is by no means homogeneous as layers of clay and sand alternate, their thickness varying very considerably in different places. It was not until the tower had been built some 20′ above ground that it was observed that it stood on a clay bed only 11′ thick and that 7′ of that had been dug out for the foundation. Underneath is a water bearing sand. If any settlement has occurred it does not appear to have injured the tower.

JAMSHEDPUR CENTRAL WATER TOWER. *(Plate 9.)* This tower is situated on the highest piece of ground in Jamshedpur

proper. It contains two tanks each holding about quarter of a million gallons. One tank is at ground level and the other has its floor 35 ft. above ground. The upper tank supplies all the high level area of the town, and the lower tank supplies the low level areas by trunk mains which run untapped through the high level area. The tower rests on a foundation of 4′–9″ of cement concrete. The inside diameter of the lower tank is 55 ft. The wall at the base is 3′—3″ thick, composed of an outer skin of brick work 18″ thick and inner skin 9″ thick, with a 12″ reinforced collar between them. The reinforcement is 1″ rods running round the tower and secured to vertical 1″ rods about 12′ apart. The maximum depth of water in the lower tank is 20 ft.; at this level it overflows through eight spouts on to the ground outside. From top water level of the lower tank to the floor of the upper is 15 ft. Reinforcement in that height of the walls is not necessary, but 1/2″ rods were placed 12″ apart to give greater strength to the tower. To help to carry the weight of the upper tank and of the roof a shaft of brickwork with internal diameter 16′–2″ and external diameter 22′–8″ is carried up to the upper floor. To carry the floor of the upper tank 15″ × 6″ rolled steel joists are placed radially between the shaft and the outer wall and 15″ × 6″ parallel across the shaft. On the lower flanges of the floor joists a centering was built and on the centering reinforced brick slabs were set from joist to joist. The strength of the local bricks is not enough to stand the crushing stress of the weight of water in the upper tank, so the bricks were cut so as just to rest on the edges of the joists to form a water tight junction, and were slightly bevelled towards the top, allowing the cement concrete of the floor to come down on to the top flanges of the joists. The reinforcement ran through continuously over the joists. The concrete for this floor was mixed on the ground and hoisted up ready mixed. Concreting started at 7 A.M. and went on continuously until 3 A.M. next morning. 1–2–3 concrete was used without the addition of any water proofing material and this floor has never shown any sign of dampness. The wall of the upper tank was built in the same way as the lower. At the junction of the wall with the floor of both the upper and lower tank a bitumen joint was made to allow for the inevitable movement. The central shaft was carried right up to support the roof and lantern.

Attached to the lower tank is the semicircular valve chamber covered with a half dome. Into this comes the 18″ rising main from the pumping station. It breaks up sending a 10″ branch to Kadma, a 10″ branch into the lower, and a 12″ branch into the upper tank. Bye-passes are arranged so that either tank may be cut out for cleaning. Part of the low level area of northern town can be fed at will from the upper or lower tank.

The head required to send the necessary water into the upper tank and to Kadma is the same. The margin of head available at the pumping station is small, so in case at any future time it becomes too small, for the duty, space has been left in the valve chamber to put in a middle floor with boosting pumps to add the necessary pressure to the water in the mains. The necessary blank flanges for this purpose have also been provided. To make the half domed roof of the valve chamber strong enough to carry any weight if machinery has to be installed would have been difficult, so a triangular structure of 6 steel beams, three forming a horizontal triangle and the other three a pyramid on it as a base, was erected on the walls. This actually carries the weight of the upper part of the half dome, and it also carries the cast iron grid floor which is reached by a reinforced concrete spiral staircase. From this landing iron steps lead to the entrance into the tower above T.W.L. of the first tank, through which go the inlet pipe to the lower tank and the inlet and outlet pipes of the upper. The inlet to the lower tank runs on a platform to the centre where it discharges through a float valve which comes into action if the lower tank fills before the upper. Access to the bottom of the lower tank is given by a steel ladder.

A circular shaft leads up through the upper tank to the space above T.W.L. In the shaft are the inlet pipe which discharges free into the upper tank over the top of the shaft, and a spiral staircase which is placed at one side to allow of hoisting materials by means of a tackle hung from a beam placed over the shaft.

A cantilever platform runs all round the upper tank giving access to the gauze covered openings which are protected outside by a reinforced concrete chajja. A steel ladder leads down to the floor of the tank.

The conical roof is supported on a steel frame work like the ribs of an umbrella. The roof itself is made of 3″ reinforced brick work resting on the steel frame work. It is covered with a glass mosaic of broken soda water bottles set in cement. This glass mosaic glistens in bright sunlight and at other times looks like old copper.

The top of the tower is flat, over a ring of gauze covered openings. A manhole leads through the roof. For convenience when repairs are necessary iron rings are built into the masonry all round the top of the cone.

The difficulty of maintaining the water supply in the town in the hot weather was such that during one hot season when the lower tank was built up to T.W.L. it was used as a balancing

reservoir. This lengthy test disclosed a few points in the walls which were not water tight, and they were grouted up. The whole of the inside of the lower tank was cement rendered with a cement gun. The difficulties of this operation are described in a paper published in the proceedings of the Institution of Mechanical Engineers in December 1925. The rendering was hard throughout but at a few points was slightly porous. This was cured with Czerelmy's Petrifying Liquid.

When the upper tank was complete except for its cement rendering it was filled with water. A great many places in the walls sweated, some leaked and two even squirted. To see what was wrong the inner brick lining was cut out at the worst places. It was then found that the work on the core joint had been carelessly done, and that enough fine mortar had not been used at the beginning of the day's work to ensure close contact with the previous day's work. All such places were made completely water tight by setting in 2″ pipes and leading them up above T.W.L. and grouting therefore under greater pressure than the water could ever exert subsequently. After all leaks were stopped the inside was cement rendered. To erect a scaffolding from the floor of the tank would have been a long, tedious and expensive job as all the material would have to be hoisted in and out again through narrow openings high above ground level. Instead barrels and and planks were hoisted up and rafts were made. The rendering was then done from the rafts. A little water was let out each day: enough to allow the men to plaster another ring. This method was not entirely successful because the bricks were so porous (all the local bricks are very poor) that they held water like a sponge, and let it ooze out just sufficiently to prevent the rendering holding continuously to the brickwork. After two or three months' use the tank was emptied and the loose patches cut out, and replastered.

The architectural features of the tower were designed by Mr. G. Wittet, F.R.I.B.A. The sunk panels are plastered with grey cinder mortar which has the effect of making the pilasters of sand plaster stand out very plainly.

It was originally intended to regulate the supply to the tower by a telephone system from the pumping station nearly two miles away; but experience has shown that it is necessary to keep men always on duty in the tower to balance the supply in top and bottom tanks. The presence of these men is convenient as they can be called for minor plumbing repairs, or in case of trouble in the night.

That the tanks have remained entirely free from algoid growths during four years' use is believed to be due to the presence

of a very slight amount of chlorine left from the chlorination at the purification works.

JAMSHEDPUR KADMA RESERVOIR. *(Plate 10.)* The Jamshedpur water supply system is designed to be fed from a number of reservoirs placed in commanding situations, each intended to hold approximately one-third of the day's supply for the area that it serves. Of the proposed reservoirs two have been built, serving three areas as one of the towers containing two tanks. The Kadma reservoir holds 270,000 gallons. It is built on a rock the top of which is sufficiently high to command the whole area. All loose and rotten pieces of the rock were cut out: the fissures were filled with 1 3 6 concrete: and a floor of 7 inches of 1 2 4 concrete laid over that. The walls are two rings of brick. work 9″ outside and 9″ inside with a 6″ reinforced collar joint. The roof is carried on the outside wall and on a shaft near the centre which is carried up to form an access chamber. It is a flat reinforced brick slab laid over radial beams and covered with lime concrete. The access chamber is covered by a Saracenic dome. This dome was built without any centering. Each course was started by fixing spikes in the course just finished and working round from them until the ring was complete. As the rings closed in each man had a helper to hold the bricks just set until the ring closed. Under the final opening when it became too small for a man to work a few planks were placed and the gap was filled from outside. This reservoir is at a lower level than another filled through the same rising main, so is controlled by a ball valve. The inlet pipe goes up the outside of the wall with a vertical iron access ladder beside it. The outlet is through a bellmouth in the floor. There is a wash out connexion to the delivery main, and a bye pass provides for pumping direct from the rising into the delivery main when necessary. Ventilation and light are given through 3′×3′ gauze covered windows situated above top water level and just under the roof. They are protected by a chajja which goes all round the tower and shades the walls to a considerable extent from the sun.

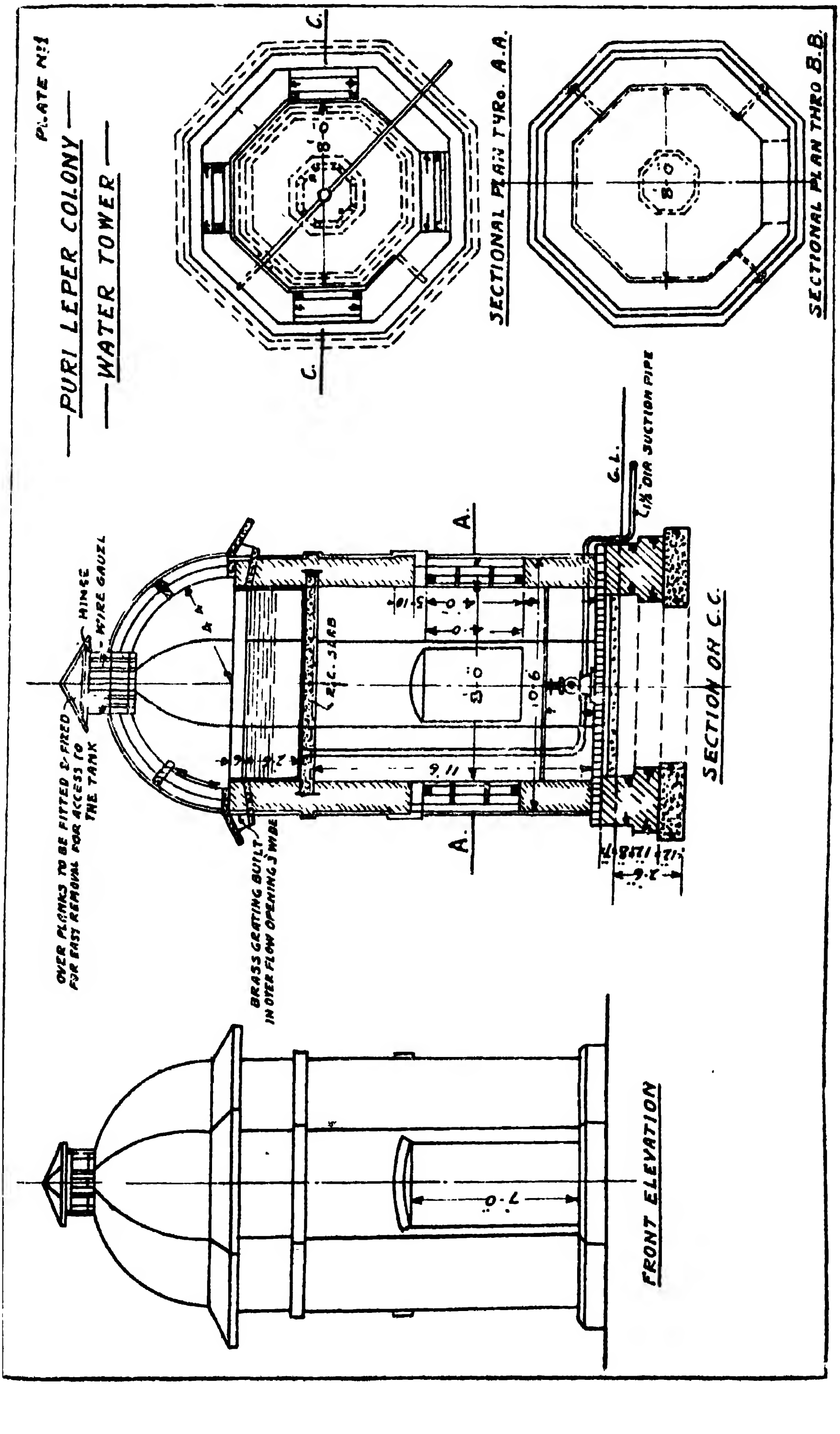
The remaining two are only designs which will very likely never materialise.

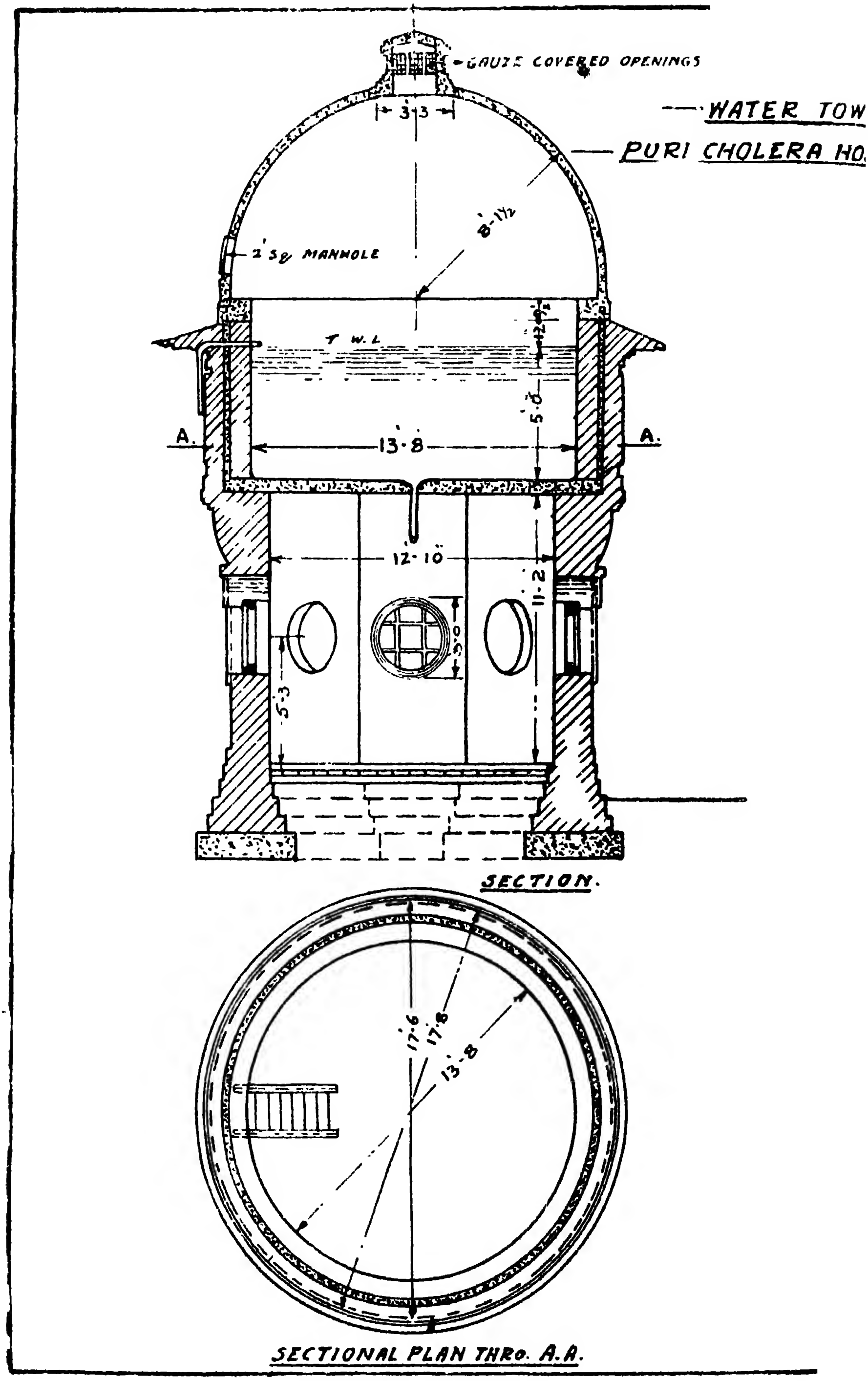
SITAMARHI RESERVOIR. *(Plate 11.)* The scheme for a waterworks at Sitamarhi was designed at a time when much interest was being taken in minor waterworks schemes. The idea at the back of these schemes was that by finding a small source of water and erecting a pump and an overhead tank with a small filter the advantages of a filtered water supply might be demonstrated to

a small part of a town. The idea was totally unpractical but it was sponsored by the people who had the money, and much good explanatory boring work was done, disclosing among other things a sweet non-ferruginous Artesian water underlying Balasore and a very extensive water bearing sand underlying Sitamarhi. The Sitamarhi 4″ bore hole behaved very well under test and it was accepted that a regular supply of 50,000 gallons a day with occasional demands of 75,000 could be obtained. The reservoir designed to deal with this was to hold 50,000 gallons. Here as in the Muzaffarpur reservoir it is proposed to provide access to the tank through a central shaft. The design differs from the others in that the annular tank should have its floor dished so as to put all the steel in tension. If the author had to build this now he would alter the design and make the floor flat or even arch it upwards so as to put the concrete in compression. Experience has shown how much easier it is to make concrete watertight against compression than against tension.

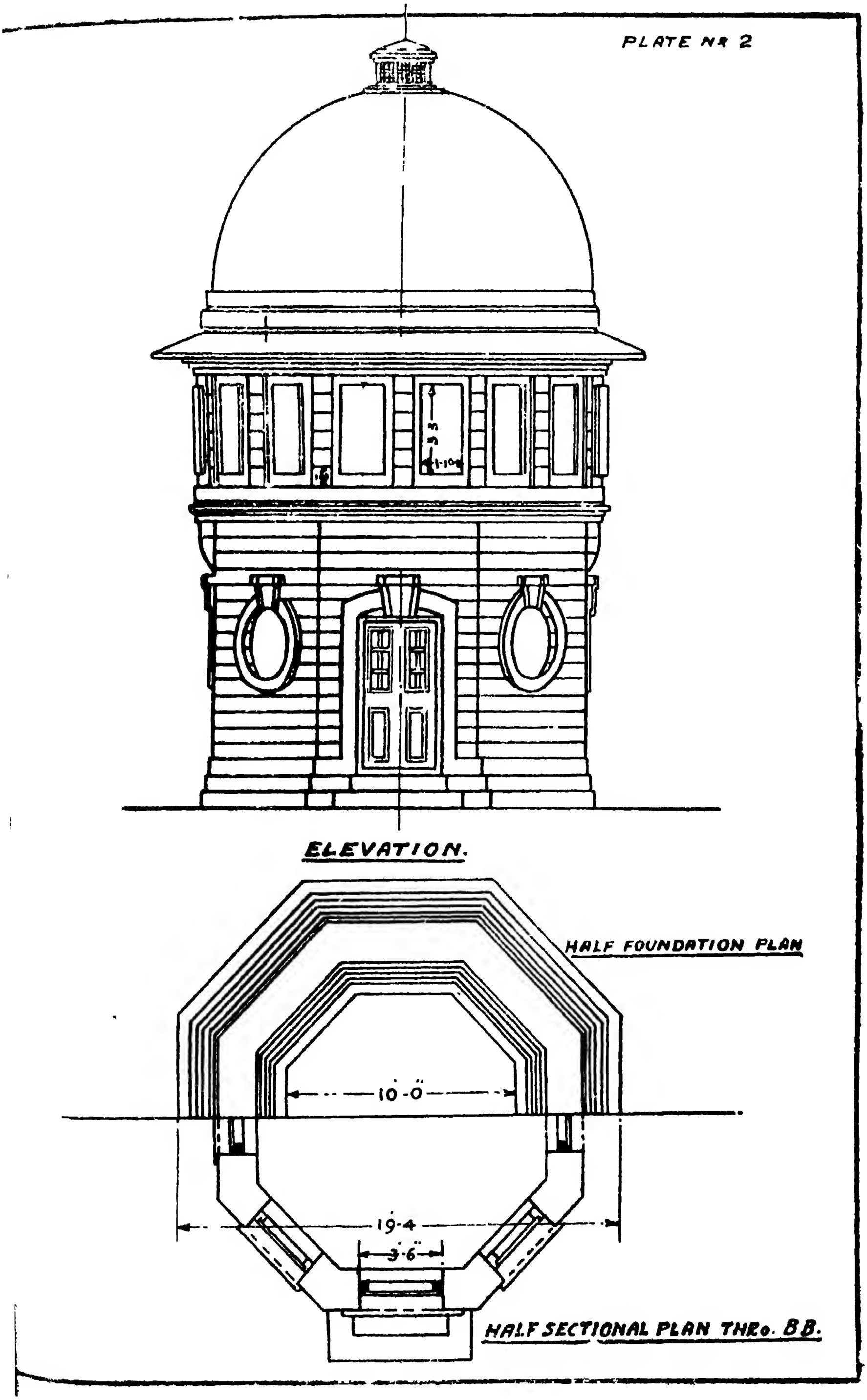
DALTONGANJ RESERVOIR. *(Plate 12.)* The town of Daltonganj lies along the side of a hill. Its water supply is from the East Indian Railway tank, through a pair of Jewell pressure filters. These filters were a great disappointment as they frequently delivered muddy water into the town. This was not the fault of the filters. They never had a chance. They delivered direct into the town mains, and at times of maximum demand were called upon to pass much more water than they were designed for. The proposed reservoir was intended to balance the supply and demand. It was to be a tower containing two tanks one above the other, to supply the different levels of the town. The principal interest in this design is the architectural treatment designed by Mr. A. Millwood, Govt. Architect, to combine the tower holding the tanks, the access turret and the valve chamber in a harmonious group. The lower tank was to rest on the ground and the upper was to have a Deacon spherical dished bottom. Both inlets were to be above T.W.L. the lower being controlled by a ball valve. Both outlets were to be from the centre of the dished floors.

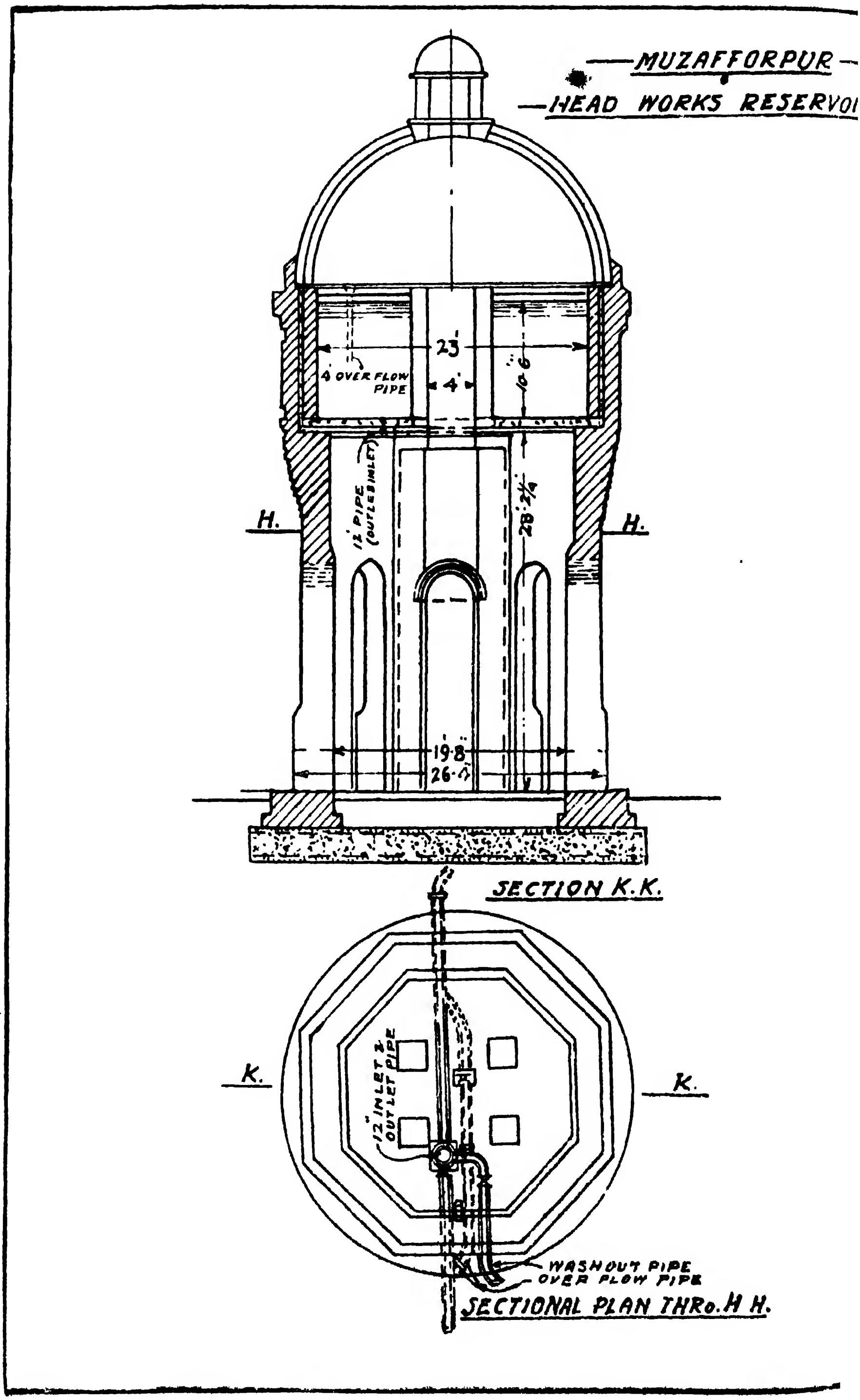
TEMPLE ON WATER TOWERS IN INDIA.




GAUZE COVERED OPENINGS
WATER TOW
PURI CHOLERA HO.
3·3
8'·1½
2' Sq MANHOLE
T. W. L
5'·0"
A.
A.
13'·8
12'·10"
11'·2
3'·0
5'·3
SECTION.
17'·6
17'·8
13'·8
SECTIONAL PLAN THRo. A.A.

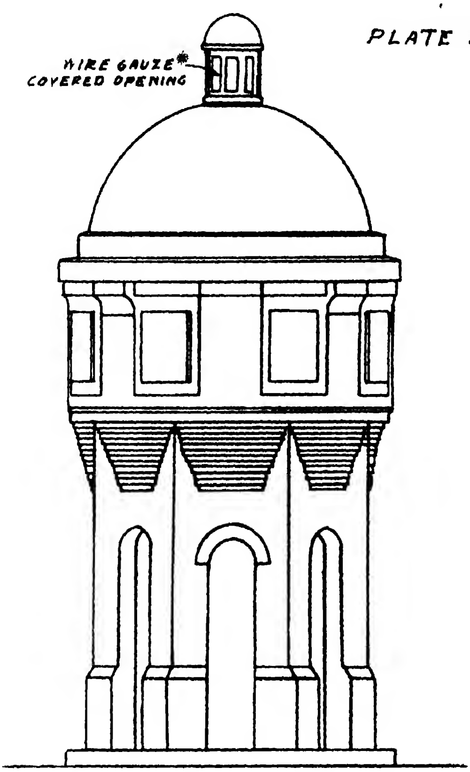
TEMPLE ON WATER TOWERS IN INDIA.



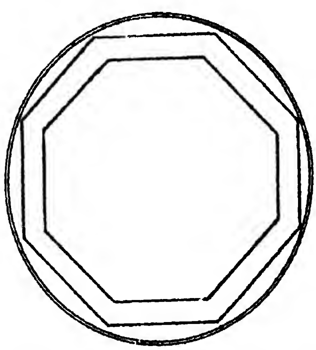

—MUZAFFORPUR—
—HEAD WORKS RESERVOI
23'
4 OVER FLOW PIPE
4'
10'6"
12" PIPE (OUTLET & INLET)
28'2¼"
H.
H.
19'8"
26'0"
SECTION K.K.
K.
K.
12" INLET & OUT LET PIPE
WASHOUT PIPE
OVER FLOW PIPE
SECTIONAL PLAN THRo. H H.

TEMPLE ON WATER TOWERS IN INDIA.

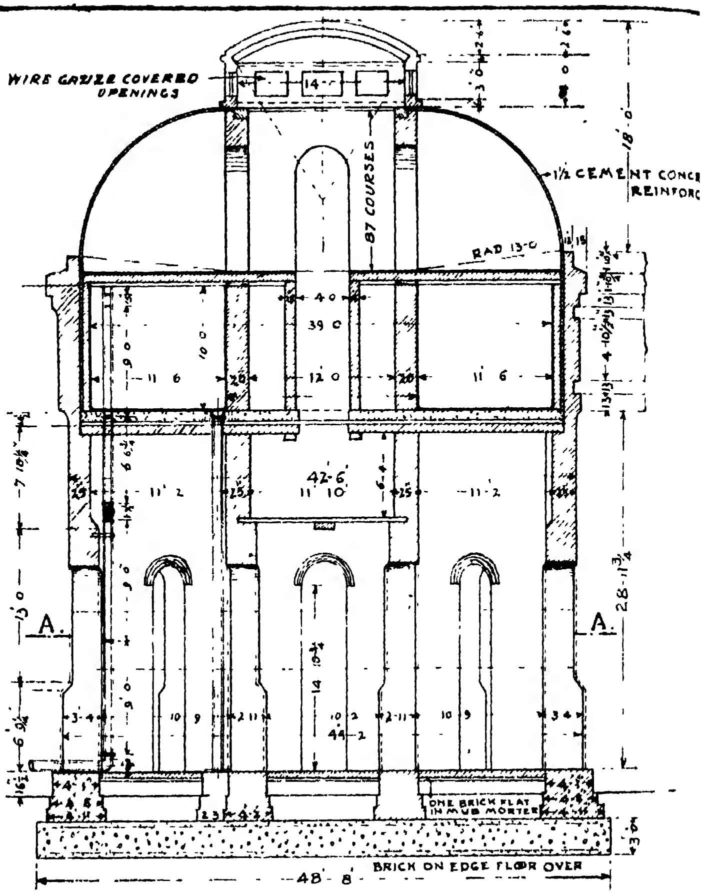
PLATE № 3



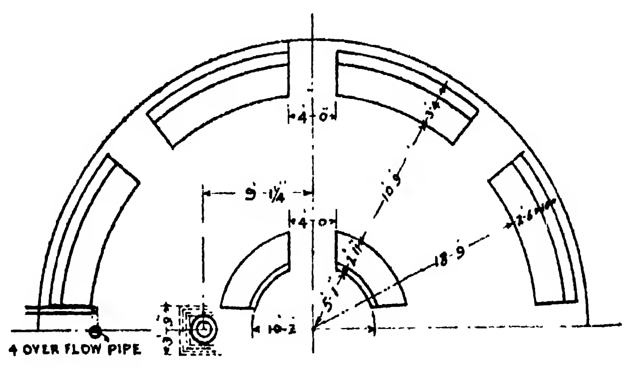
ELEVATION



INVERTED PLAN SHOWING CORBELLING

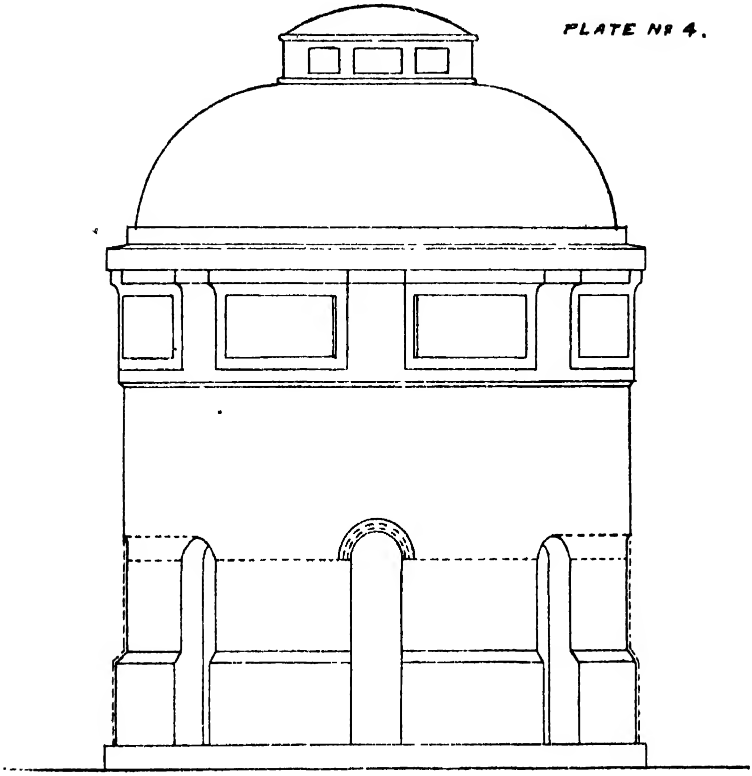


SECTION ON D.D.



SECTIONAL PLAN THROUGH A.A.

PLATE Nº 4.



ELEVATION

MUZAFFORPUR

SOUTHERN RESERVOIR

70,000 GALLONS

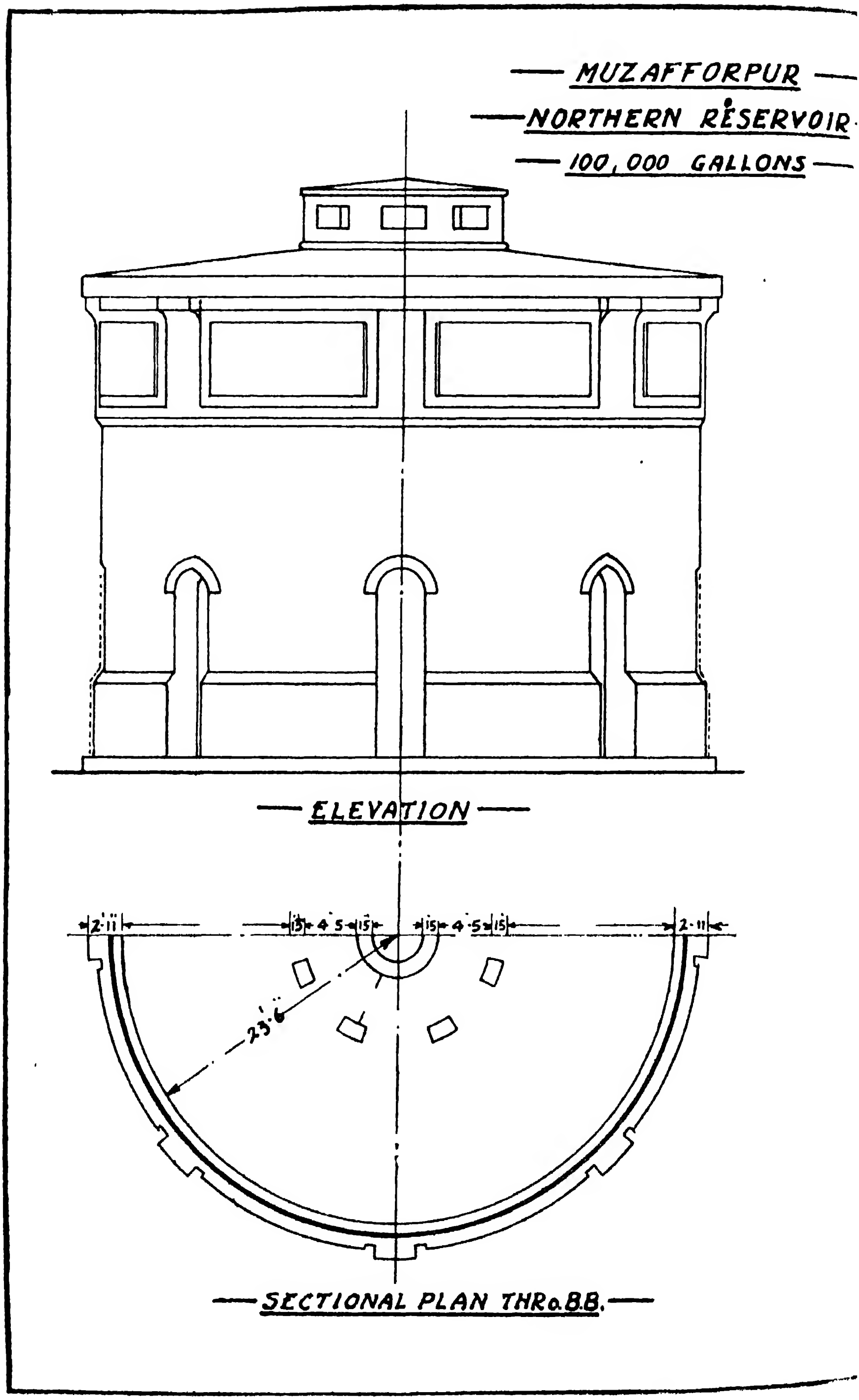
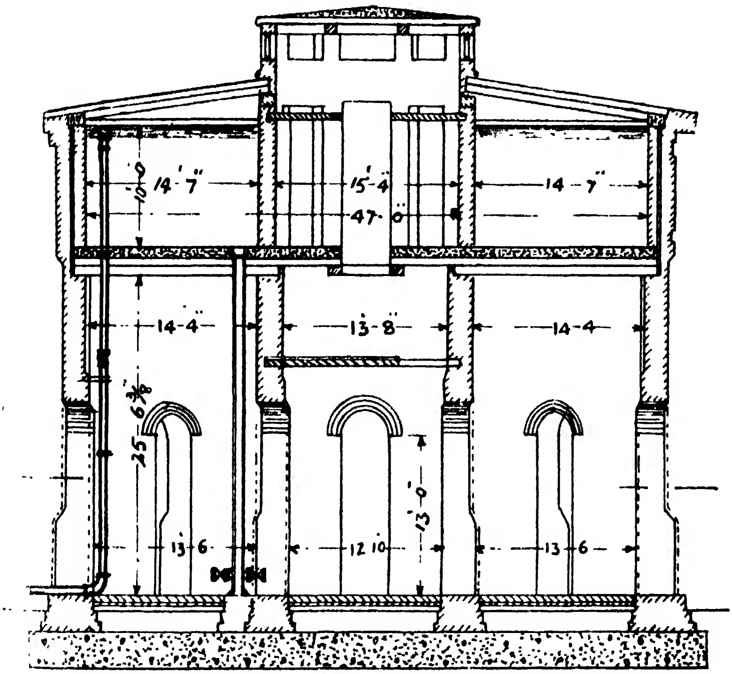
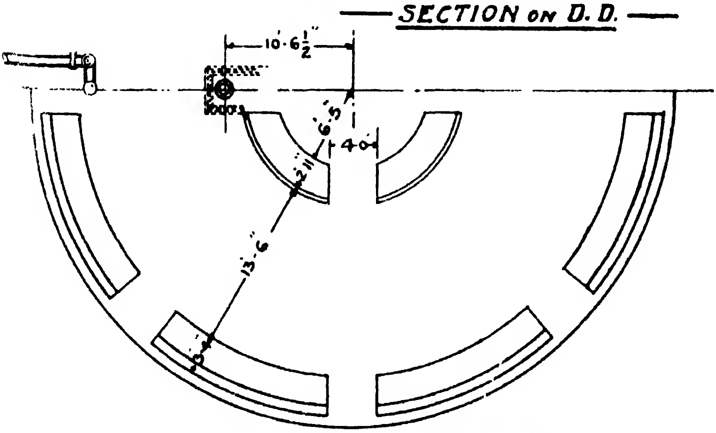

MUZAFFORPUR
NORTHERN RESERVOIR
100,000 GALLONS
ELEVATION
2·11
15
4 5
15
15
4 5
15
2·11
23'6"
SECTIONAL PLAN THRo. B.B.

PLATE No. 5



SECTION on D. D.



SECTIONAL PLAN THRo. A. A.

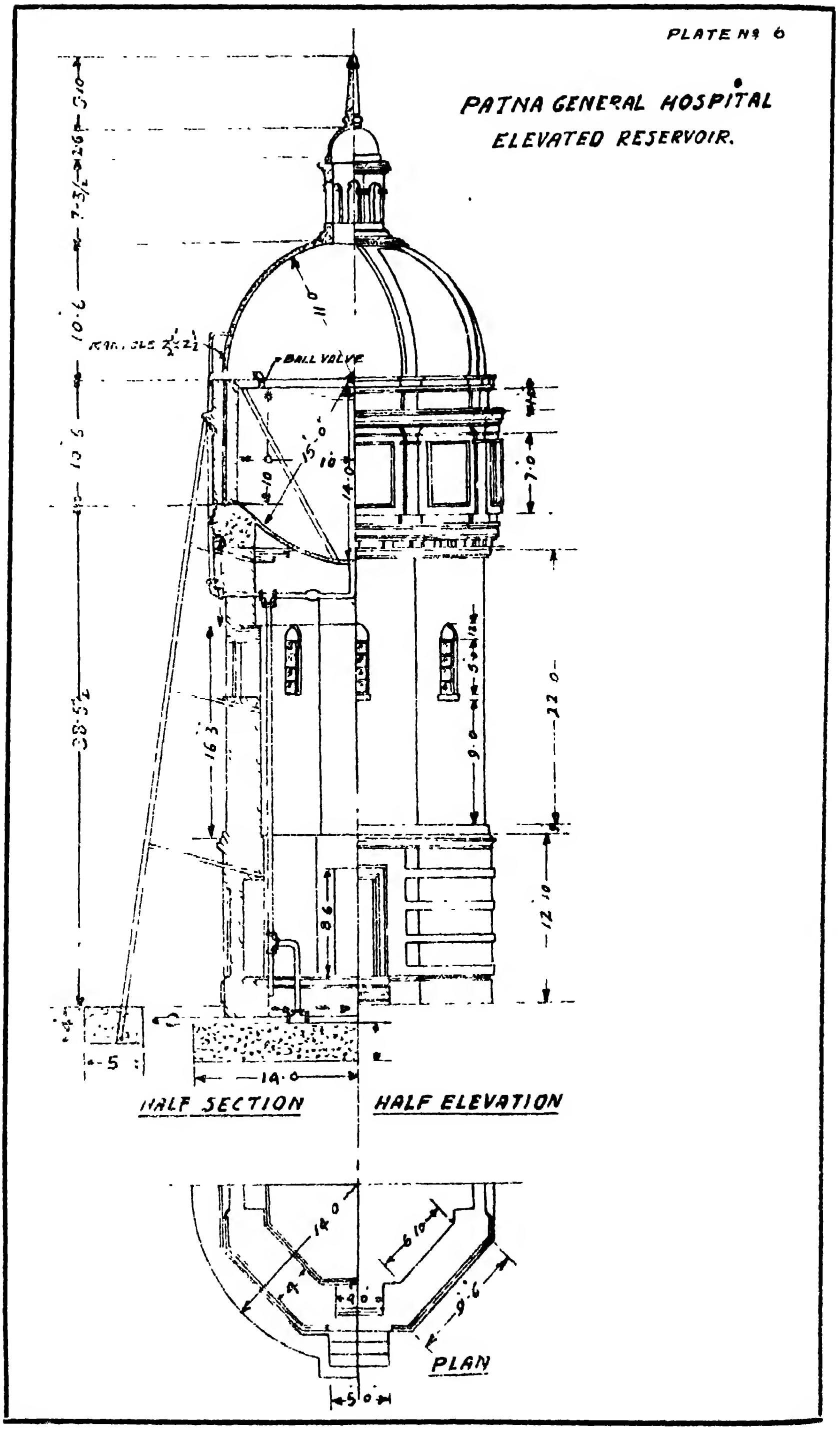


PLATE No 6
PATNA GENERAL HOSPITAL
ELEVATED RESERVOIR.
BALL VALVE
HALF SECTION
HALF ELEVATION
PLAN

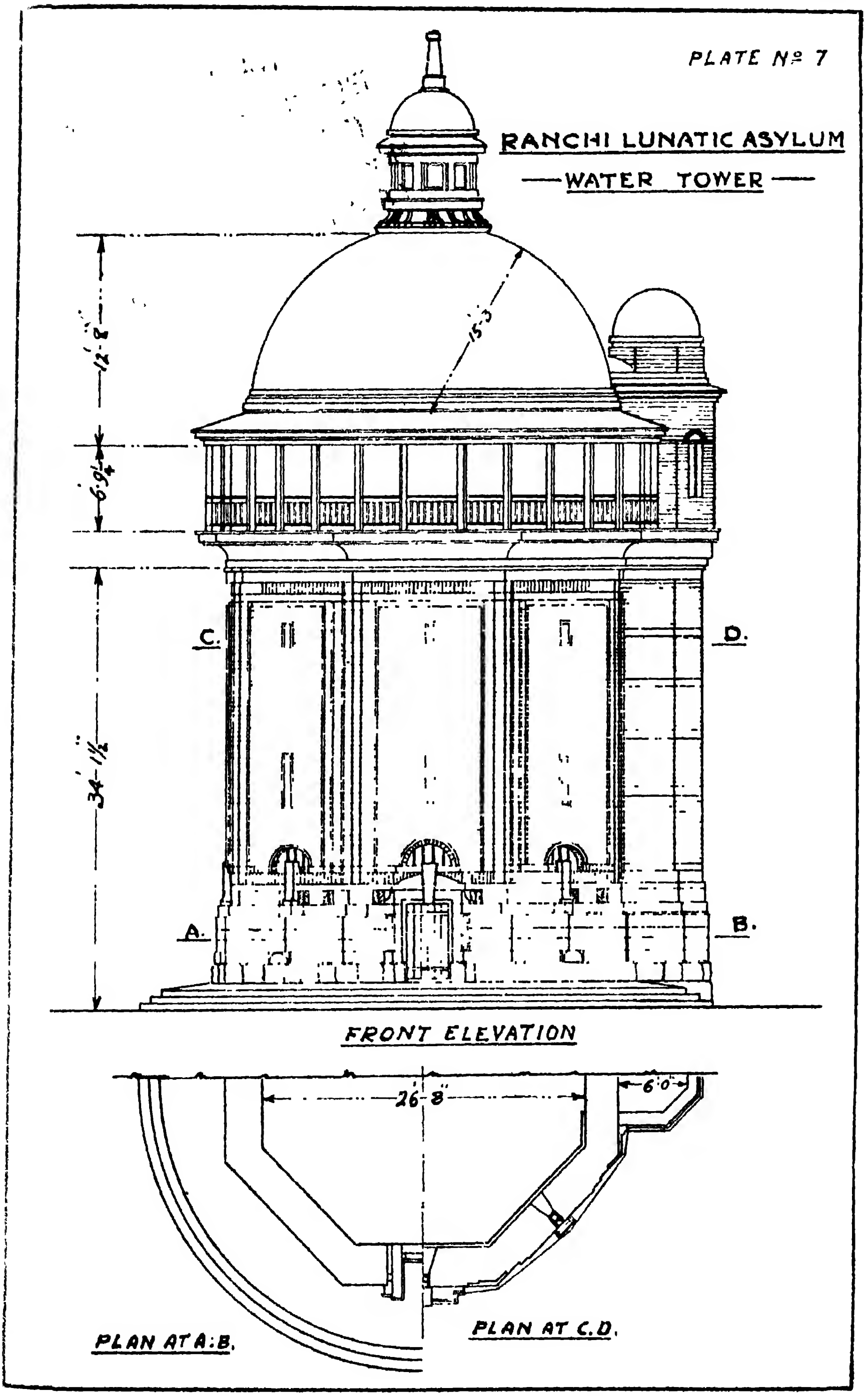
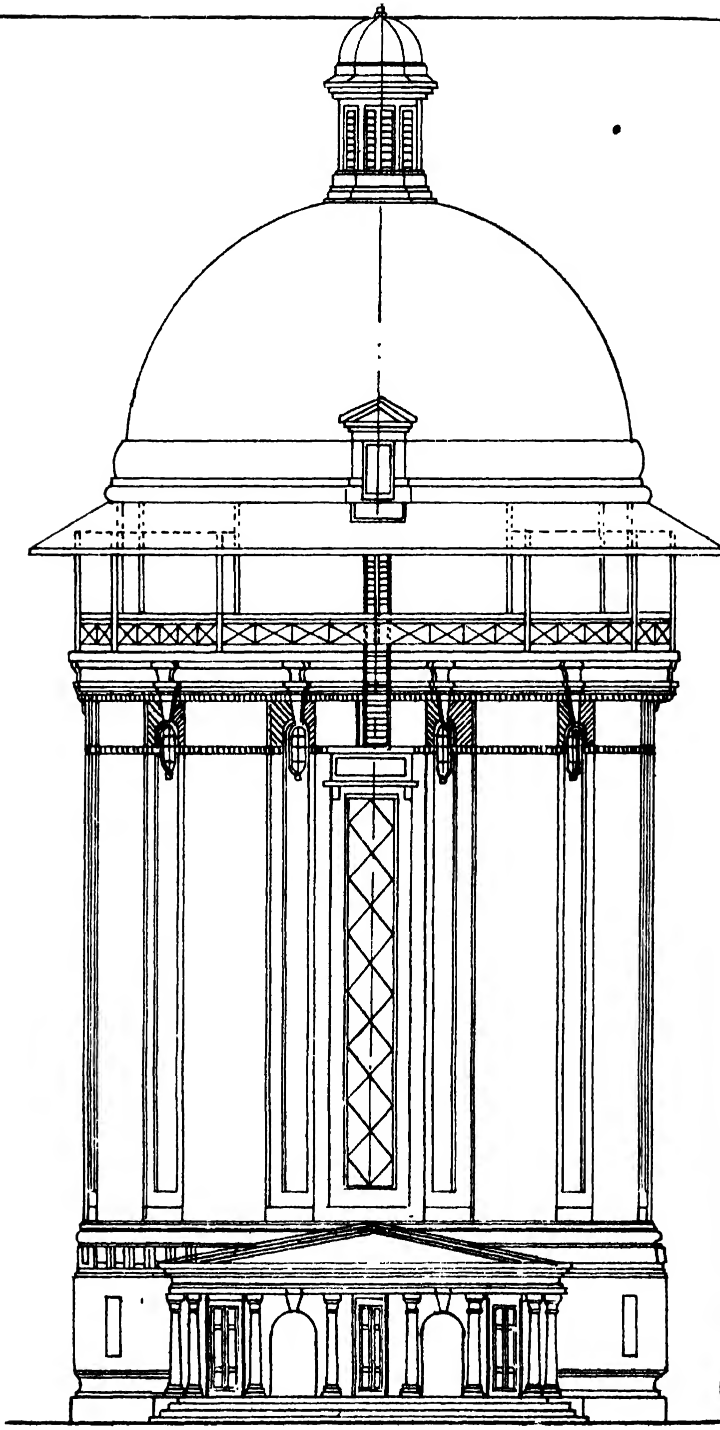


PLATE № 7
RANCHI LUNATIC ASYLUM
WATER TOWER
12'8"
15'3"
6'9¼"
34'-1½"
C.
D.
A.
B.
FRONT ELEVATION
26'8"
6'0"
PLAN AT A:B.
PLAN AT C.D.

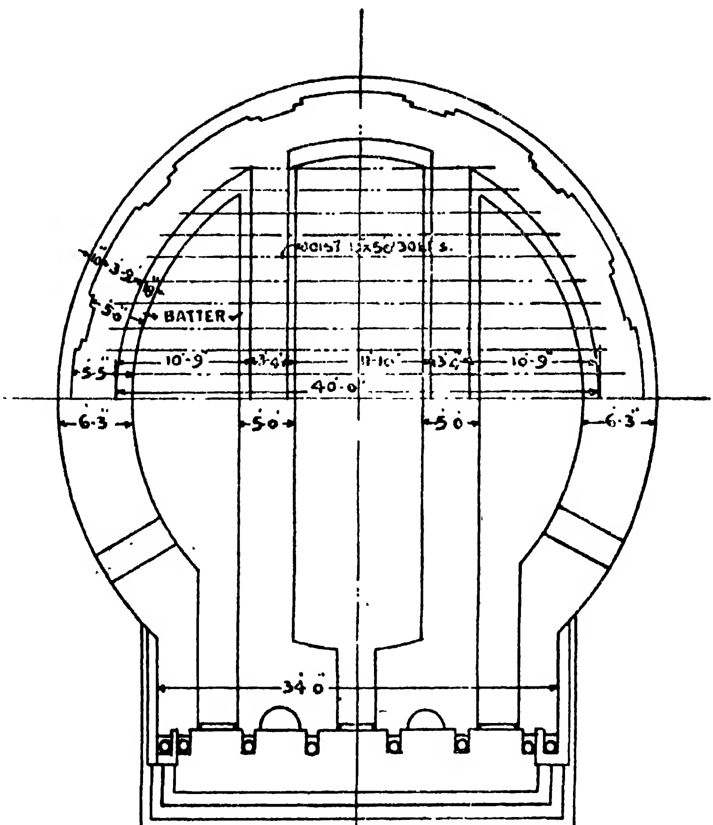


—FRONT ELEVATION—

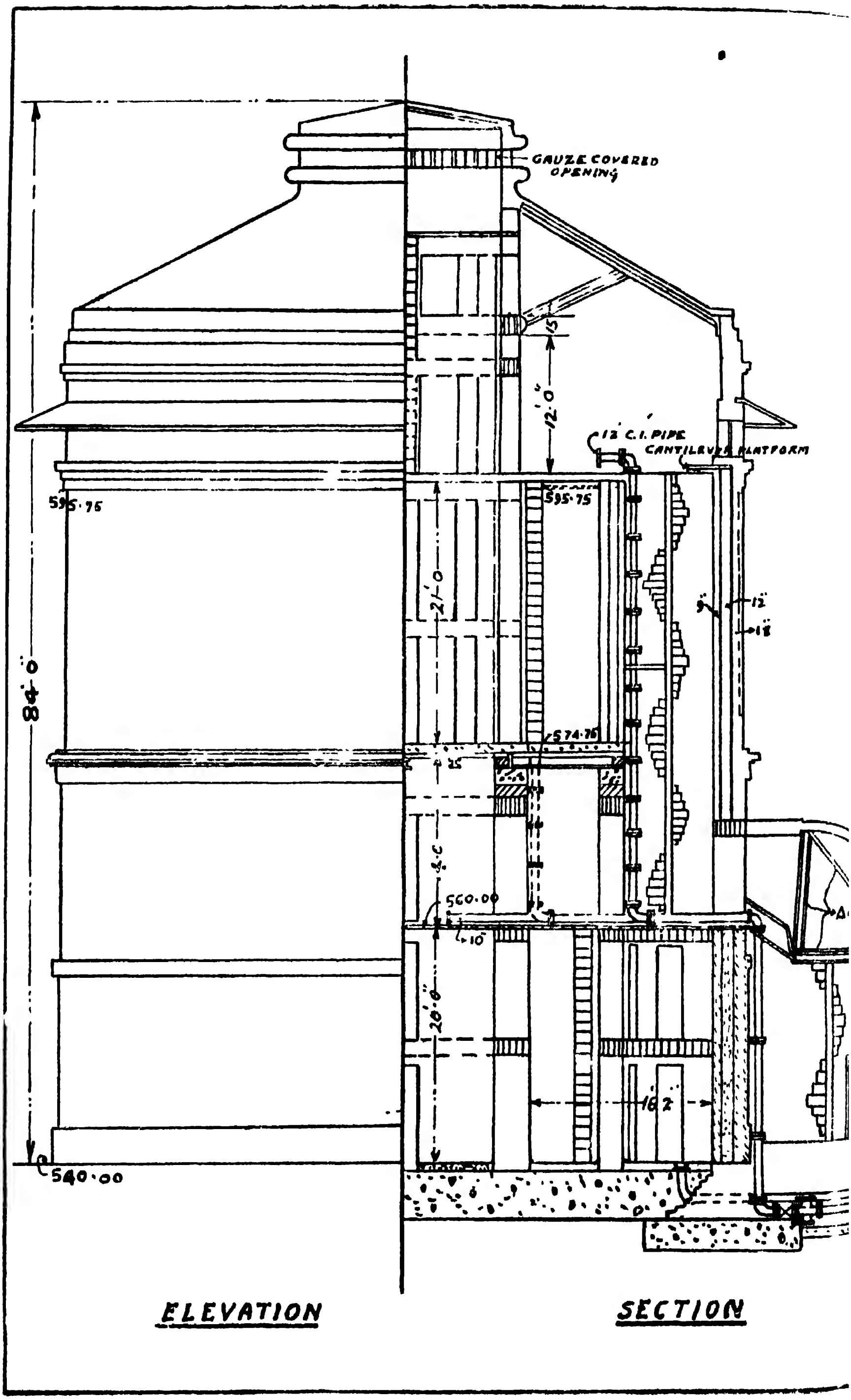
PLATE No. 8

PATNA NEW CAPITAL

WATER TOWER

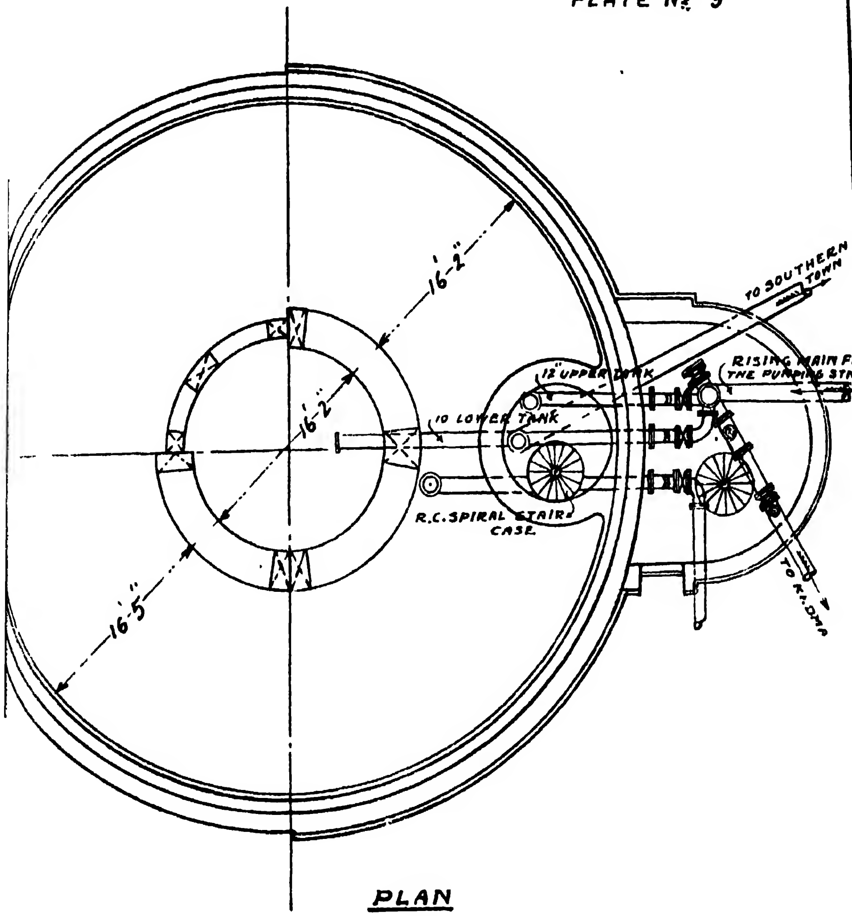


PLAN



GAUZE COVERED OPENING
12 C.I. PIPE
CANTILEVER PLATFORM
595·75
595·75
574·75
560·00
540·00
84'-0"
12'-0"
21'-0"
20'-0"
18'-2"
ELEVATION
SECTION

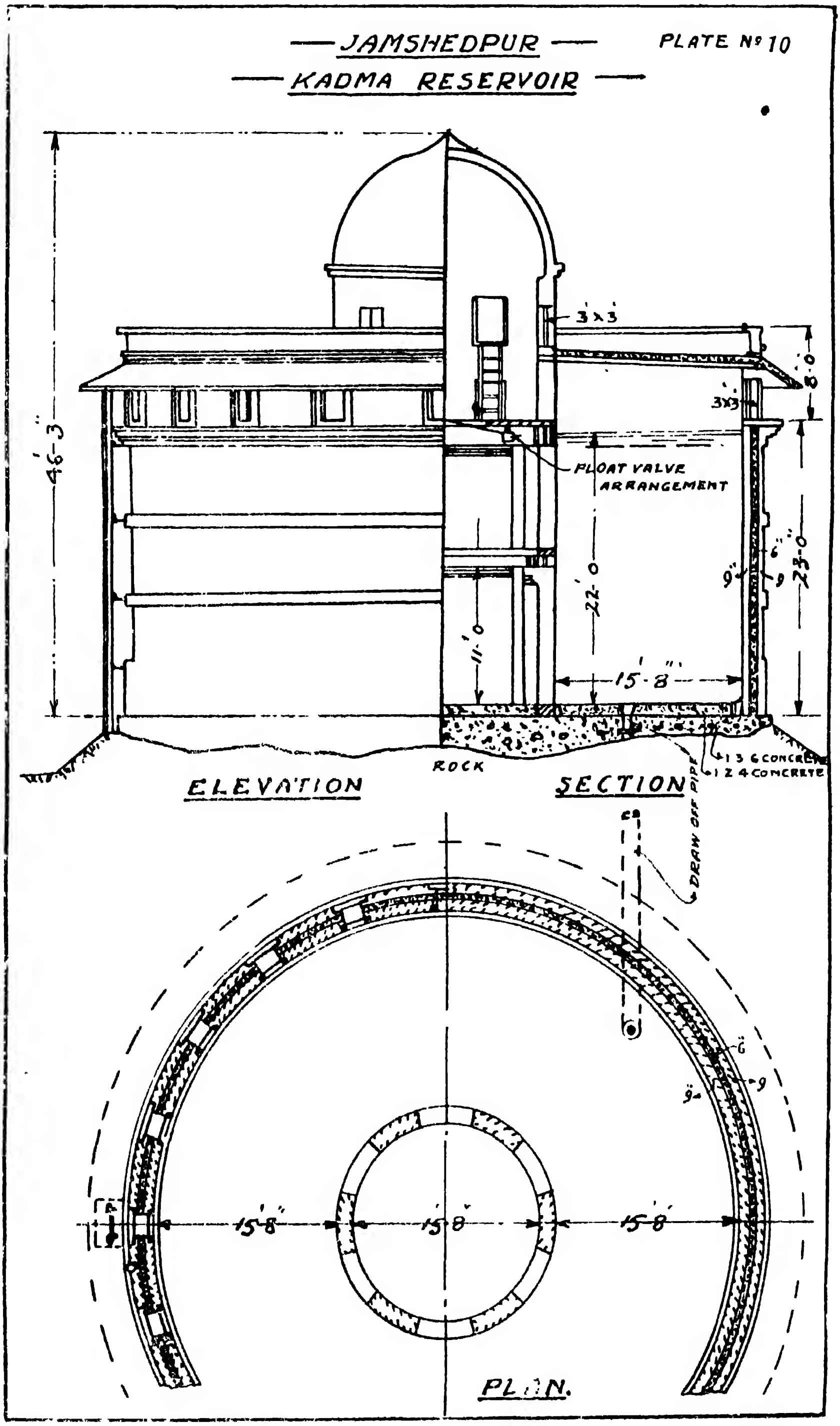
PLATE No. 9



PLAN

— JAMSHEDPUR —

— CENTRAL WATER TOWER —


JAMSHEDPUR
PLATE No 10
KADMA RESERVOIR
46'-3"
3'x3'
3'x3'
8'-0"
FLOAT VALVE ARRANGEMENT
22'-0
23'-0
11'-0
6"
9"
9
15'-8"
1:3:6 CONCRETE
1:2:4 CONCRETE
ROCK
ELEVATION
SECTION
DRAW OFF PIPE
6
9
9
15'-8"
15'-8"
15'-8"
PLAN.

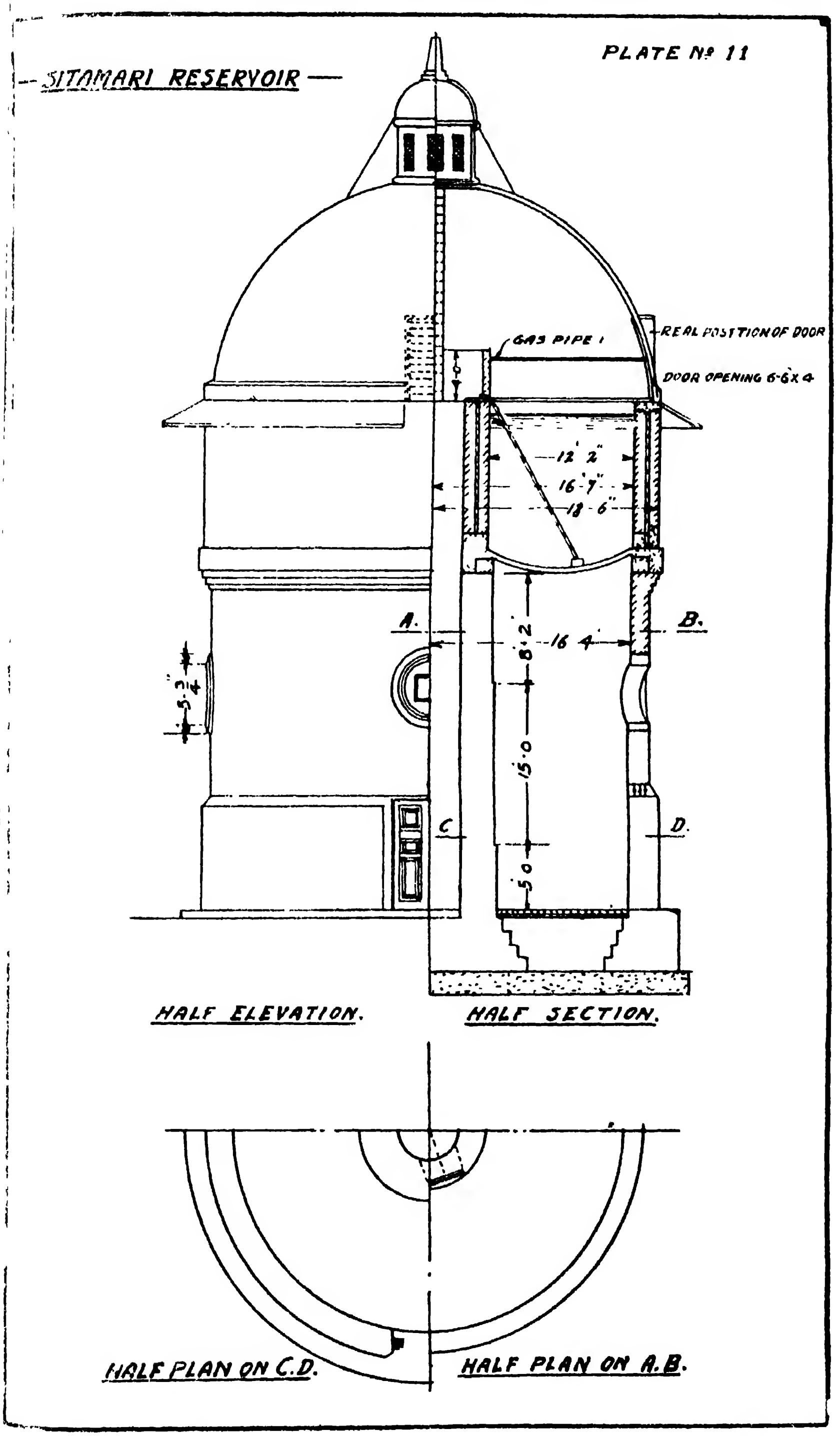
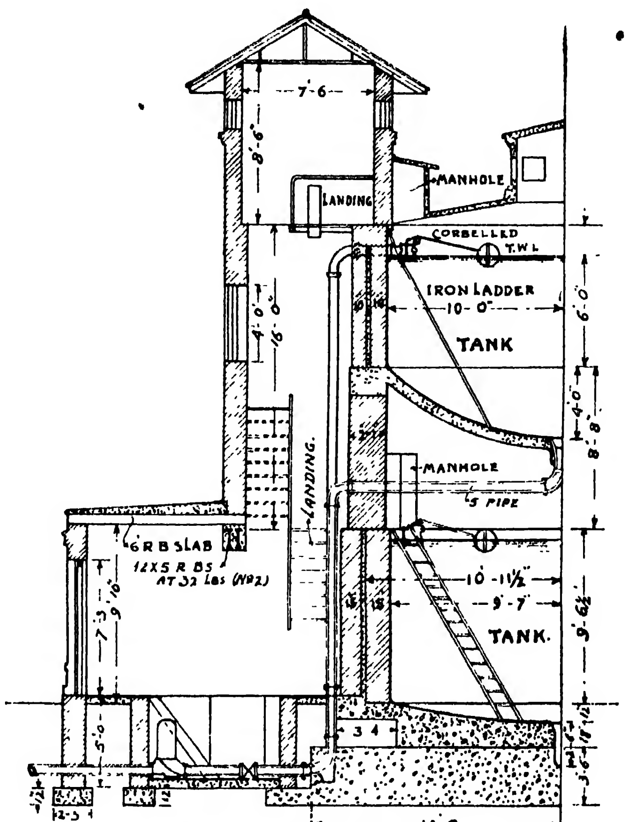
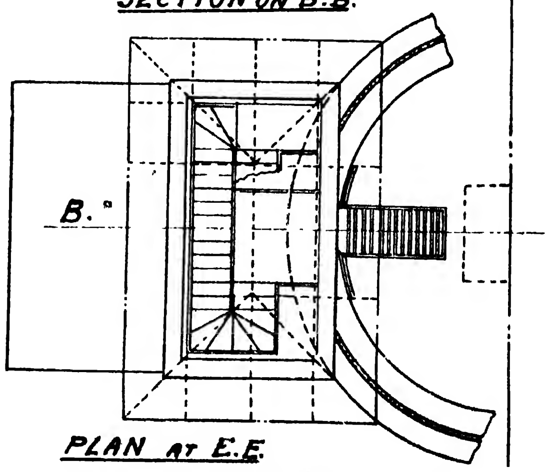


PLATE No 11
SITAMARI RESERVOIR
GAS PIPE
REAL POSITION OF DOOR
DOOR OPENING 6-6 X 4
12' 2"
16' 7"
18' 6"
A.
B.
16' 4"
8' 2
15' 0
5' 0
C.
D.
HALF ELEVATION.
HALF SECTION.
HALF PLAN ON C.D.
HALF PLAN ON A.B.

—DALTONGUNG RESERVO

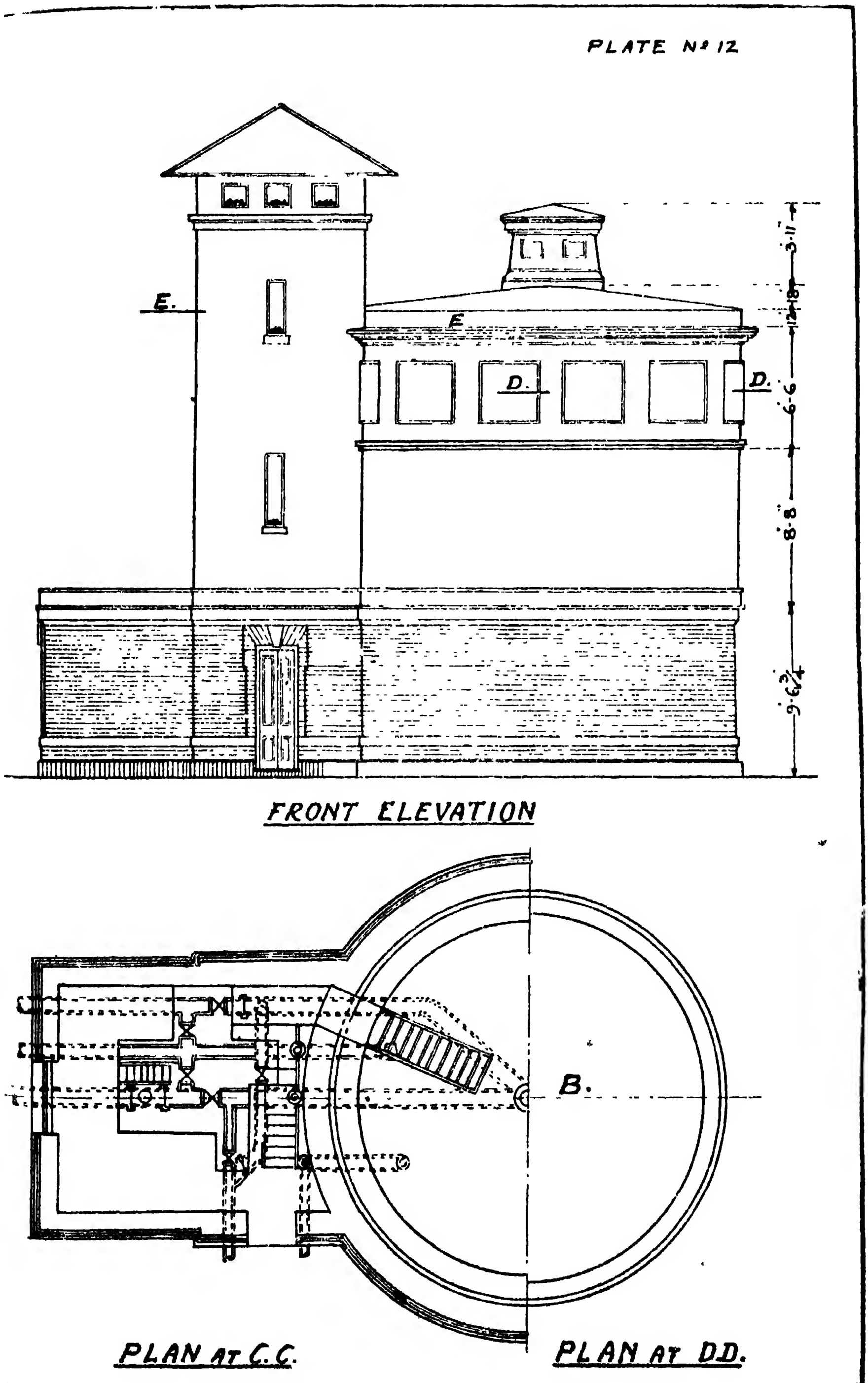


SECTION ON B.B.



PLAN AT E.E.

PLATE No 12


E.
E
D.
D.
3·11"
1·2½
1·8
6·6
8·8
9·6¾
FRONT ELEVATION
B.
PLAN AT C.C.
PLAN AT D.D.

DISCUSSION ON SOME WATER TOWERS IN INDIA.

Mr. G. Bransby Williams

MR. G. BRANSBY WILLIAMS remarked that Mr. Temple's paper on water towers was particularly interesting to him, for he had probably designed and erected more water towers than anyone else in India. Most of the structures for which he had been responsible were he must confess more useful than ornamental in which respect he thought they resembled the majority of the towers illustrated in the paper. The truth was that it was extremely difficult to design a water tower that was satisfactory from the aesthetic point of view, unless it was made to look entirely unlike a water tower. This problem was one of many that raised the wide question of engineering architecture, which, he might confess, was a subject on which it had been his ambition to write a treatise, in the time (that ever seemed to get more remote) when he could desert the purely utilitarian side of his profession and devote himself to the philosophical contemplation of its theoretical and psychological aspects.

His view was that what was required in the civil engineering world was a class of men who specialised in engineering architecture. It was difficult to say whether more monstrosities were produced when the ordinary architect tried to design engineering structures, or when the average engineer endeavoured to do an architect's job. A structure derived a certain beauty from being entirely suited for the purpose it served, but it could acquire nothing but ugliness from meaningless excretions. As an example of this thesis he might point out that nothing could be more graceful and suitable to its surroundings than Brunel's eliptic brick arch over the Thames at Maidenhead. If all engineering architecture were planned on similar simple lines the present day world be much more beautiful for it.

He was taking the liberty of shewing a photograph of the water tower he had recently designed and erected at Cooch Behar, in which he ventured to say, to some extent at all events, his principles were illustrated. He did not suggest that it was an ideal structure but he did think it reached a higher aesthetic standard than most water towers in this country.

As this water tower had some interest from a purely engineering point of view, he had also shewn a plan and section of the

building. The basement served as a pumping station for the water-works. Three motor driven triple ram pumps formed the pumping machinery. Two pumps were usually in work, the third being a standby. The water supply was taken from two tube wells, the pumps drawing separately on each well. The tank itself was of steel, with a hemispherical bottom. The capacity was about 55,000 gallons. It acted as a balancing tank, the inlet and the outlet being through the same pipe. The roof was a reinforced concrete dome. The access to the tank was through a spiral staircase built in the turret which was extended above the dome of the main structure to a finial, 89 feet above ground level. Mr. G. Bransby Williams.

In regard to domes, he must confess that one remark of Mr. Temple's had puzzled him. He spoke of the lantern over the Ranchi Lunatic Asylum Reservoir as being sufficiently heavy to put the whole dome into tension. The only condition in which every part of a dome could be in tension seemed to him to be when the pressure was from inside. In such circumstances the position would be similar to that in the hemispherical bottom of a steel tank if that were inverted. If his assumption was correct we arrived at a paradox, that the heavier weight we put on the dome, the lighter it became! so if we only increased the weight sufficiently, the upward pressure would be enough to raise the whole structure from the ground and let it float away. In fact all we had to do to build an airship would be to construct a dome and put a heavy enough weight on the top. Even Einstein had hardly suggested such a complete subversion of our ideas of the force of gravity so he presumed there was some fallacy in his reasonings. He would be obliged if Mr. Temple would point it out.

Mr. J. M. Ray remarked that he deprecated the additional tower for the staircase on grounds of economy. A stair could be cheaply put in winding alongside the wall of the main tower. The space between the steel tank and the wall supporting the roof was only 2′. This he considered too narrow. It gave sufficient space for a man to go round but he thought it too cramped for workmen to do any repairs as cutting out a rivet or painting. The ventilation holes appeared to him to be inadequate from the drawing. He would like to know the reasons why Mr. Williams chose a steel tank in preference to reinforced concrete tanks—whether he found the former to be economical. His remarks on the additional tower for the staircase and comparative economy of steel and reinforced concrete tanks applied also to Mr. Temple's paper. He wanted to know Mr. Temple's opinion about the best paint to use for painting steel reservoirs. He questioned his advice of allowing a reinforced concrete floor slab to go right over the supporting wall Mr. J. M. Ray.

Mr. J. M. Ray.

as he thought the weight of the upper story wall resting on the reinforced concrete slab would prevent expansion and contraction thereby tending to produce cracks.

Mr. G Bransby Williams.

MR. G. BRANSBY WILLIAMS in reply to Mr. J. M. Ray said—The staircase tower added to the effect and did not materially increase the cost for if it had not been constructed the main tower would have had to be made larger. A space of 2′ was quite sufficient for the purpose for which it was required. The ventilation holes were 2′ in diameter and a sufficient number had been provided. It was not necessary to go into the question of comparative cost in that case for the steel tank had been adopted on account of the liability of Cooch Behar to earthquakes.

The Author.

THE AUTHOR in reply said that he very much deprecated what he was only able to describe as the gross materialism of many of the comments on his paper. The point of view appeared to be that as a water tower would probably not be beautiful, the cheapest possible structure however hideous should be erected simply because it was the cheapest. He had never agreed with that point of view and preferred masonry water towers to steel because he thought he could make them less ugly. In his architectural efforts he had been much helped by the late Mr. George Wittet, Government Architect in Bombay, who had told him never to put a meaningless string course or moulding, and to remember that shadows and openings are more noticeable and therefore more important in design than walls and pillars. An inspection of the designs attached to the paper would show that outside mouldings were almost all put where extra strength was required. For instance, in a raised tank the line of the floor might be emphasized by a moulding outside as extra strength was required at that point; and indeed one of the easiest ways of preventing leakage at the junction of walls and floor was to put a reinforced collar round the foot of the wall, so that the wall could actually stand and move in a joint of bituminous material. Again a chajja or sunshade throwing a pleasing shadow could reasonably be put over top ventilators.

The statement that a heavy lantern could put a whole dome in tension was of course very loosely worded. The formula however for calculating the stresses in a dome, given in Marsh and Dunn's Hand Book, actually gave a diagram to that effect. And it was true that a dome with a heavy lantern would fail, if it did fail, by bursting at some point possibly close to the lantern. The masonry carried the load in compression, but hoop reinforcement would be necessary to the top of the dome to prevent failure by bursting.

The Author.

He had built inside and outside staircases to give access to the tanks in his water towers and on the whole he preferred them outside, because they gave much more convenient space for pipes and valves and were very little if at all more expensive. If a stair case was put inside, the whole tower had to be enlarged to give the necessary capacity, thus adding to the cost of expensive main walls and floors and roof.

He was in favour of carrying the floors right through the walls. He thought there was less danger of cracking than when the floors were built into a recess in the wall. In the same way, he was in favour of building roofs right over walls, and starting parapets afresh on the roofs. He had never been able to understand the Indian custom of building roofs in a niche on the walls of houses and in his experience leakage nearly always occurred at that point. A flat roof was bound to move and he was in favour of letting it move on top of the walls. It was most improbable that it would move always in the same direction and so creep off the building.

He had tried many water proofing materials mixed with cement but had found that the best method of obtaining waterproof cement work was to use plenty of cement and to see that it was put in the proper place. He used a one to one cement and sand mortar to start each day's work in cement core fillings of brick walls, and arranged for raised floors to be made in one continuous operation so that work was done throughout on a 'green' face and there were no construction joints.

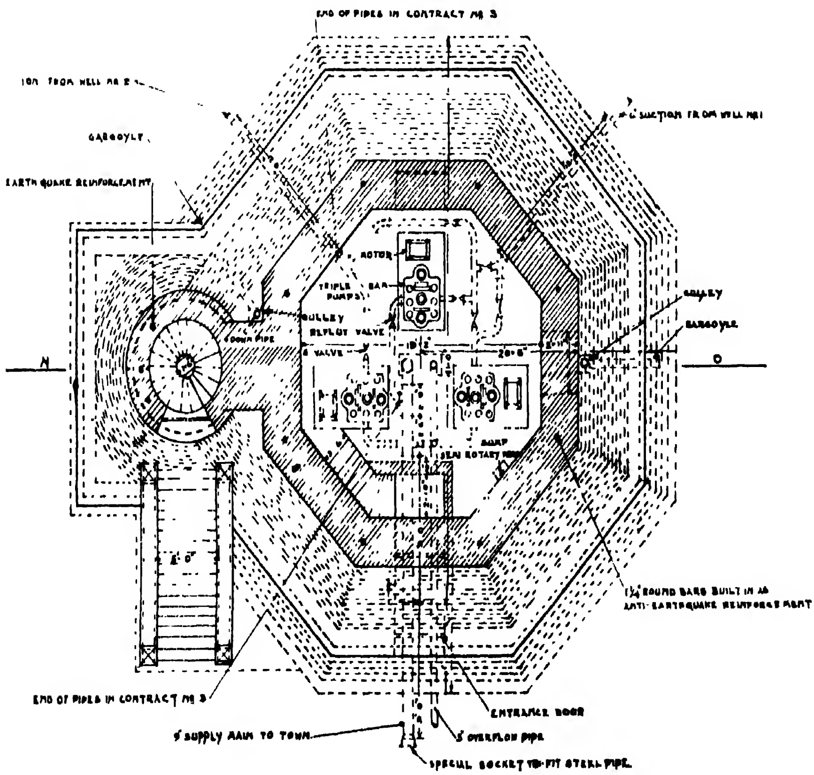
He had used cement grout forced in under pressure both by gravity and by a pump to stop leakages with some success. He did not recommend large ventilators to water tanks, as they let in too much light and thereby encouraged algoid growths. He preferred plenty of small ventilators, well shaded by a chajja.

He had tried many paints for protecting steel from rust and had not yet found one that he considered really satisfactory. This had influenced his preference for masonry or reinforced concrete tanks.

COOCH BEHAR WATER SUPP

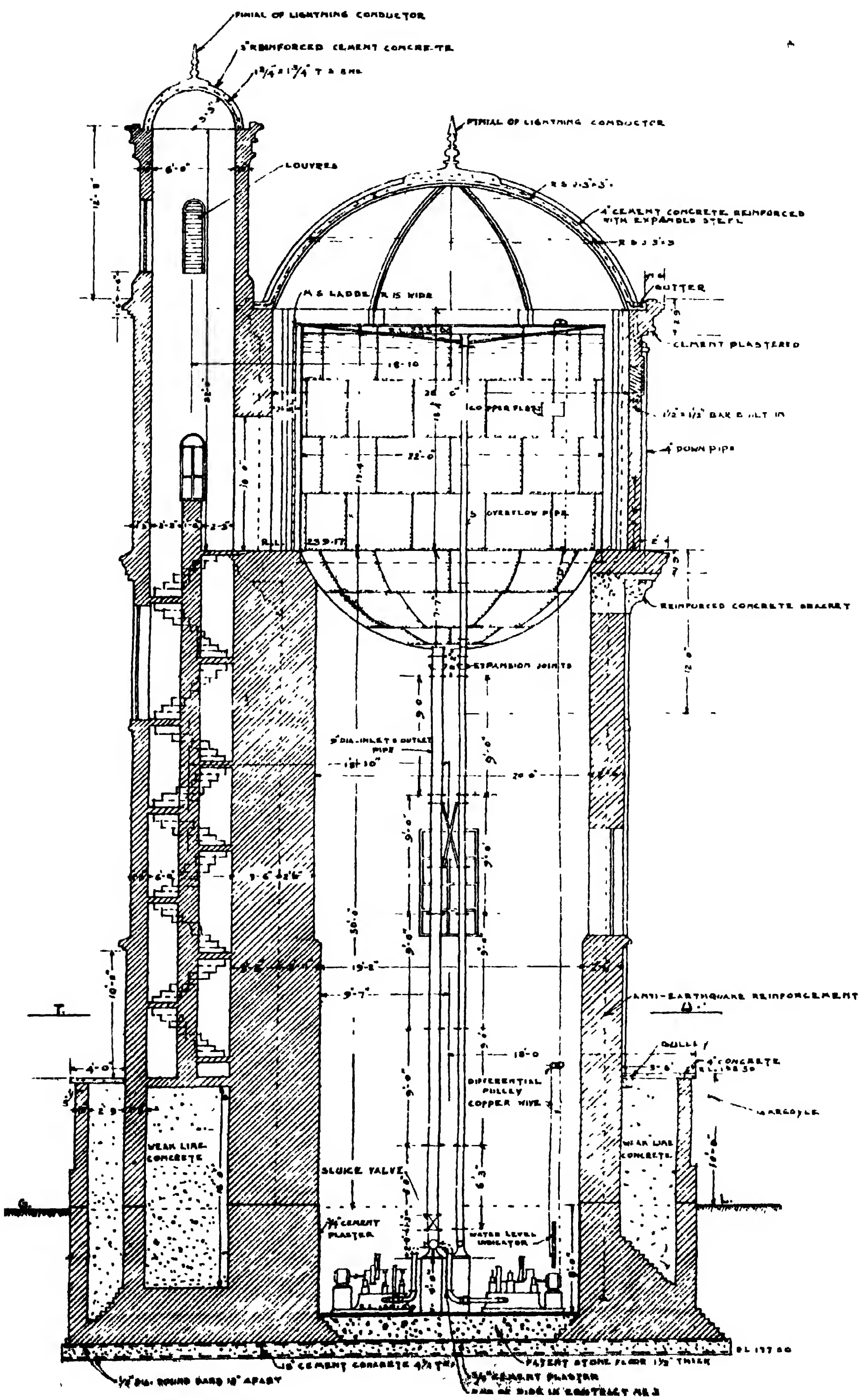
WATER TOWER.

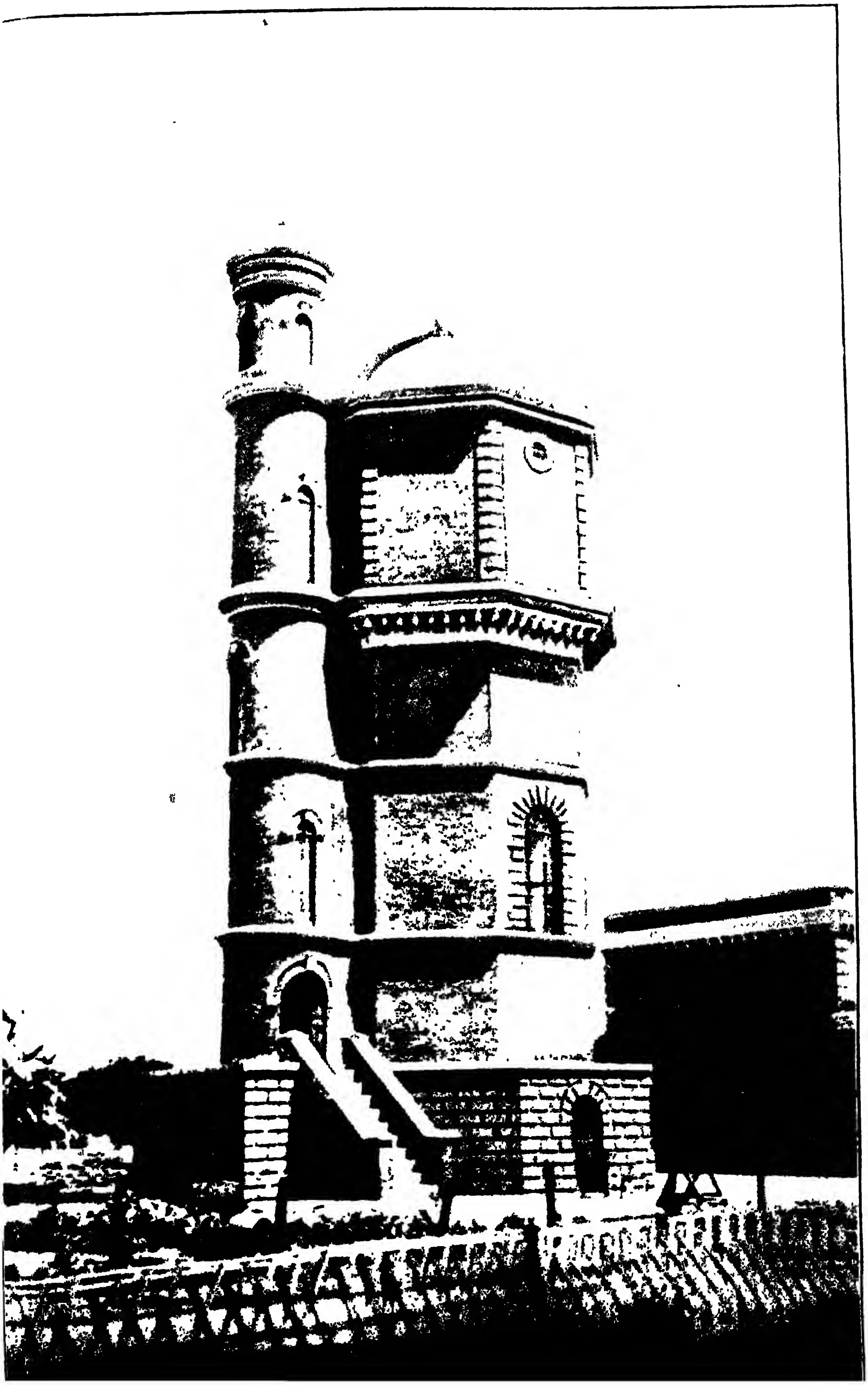
SECTIONAL PLAN AT T U.



DISCUSSION ON WATER TOWERS IN INDIA.

SECTION ON N. O.





THE RECONSTRUCTION OF THE 2'—6" GAUGE BRIDGE ACROSS THE NERBUDDA RIVER, BENGAL-NAGPUR RAILWAY

BY

C. I. STABLER, Member.

As this paper deals primarily with the salvage and reconstruction of this bridge, it is perhaps unnecessary to go into details concerning its actual wash away.

Suffice it to say that, on the 19th of September 1926, the river rose to the unprecedented reduced level of 1,282 at the Bridge site, as against the previous highest known reduced level of 1,262 feet above sea level.

The bridge consists of five 200 foot spans, and one 150 foot span, all of the Whipple Murphy type, being 17 feet over all in depth. The water rose about 1'—6" over the tops of the top booms, and when it subsided, it was found that all the spans had disappeared except one 200 foot span on the Gondia side of the river.

By the 18th of October the water had fallen considerably and all the wrecked spans were visible.

Illustration No. 1 shows their respective positions as they lay in the river bed, and the fact that one span weighing over 250 tons, had been carried nearly half a mile down stream, testifies to the great force of the current.

Illustrations Nos. 2, 3, 4 & 5, showing views of some of the wrecked spans, were unfortunately taken with a very small camera fitted with a wide angle lens, which has had the effect of making the spans appear (in some cases) much longer than they actually are, but (in all cases) much straighter and less damaged than they were at that date.

These photographs were also taken after the spans had been cleared of brushwood, tree trunks and other debris.

The damage sustained by the spans was in many instances interesting and curious.

The most remarkable feature was the paucity of sheared riveted connections. In almost every case, the steelwork of the various members had been bent and torn, while the rivets in the connections were intact. All rivets were of steel 7/8 inches diameter, except in the decking, where they were 3/4 inches diameter. Field rivets had been put in by pneumatic hammers.

All the spans except No. 6 (150 feet) had been rolled along the bed of the river before coming to rest. Thus the light overhead bracing and arching had suffered the greatest damage, while the heavy flooring, consisting of 3/8 inch deck plates laid over 10″ x 6″ rail girders and 17 inch deep cross girders, had withstood the excessive strain extraordinarily well in all cases.

So marked was this in the case of No. 4 Span, which had been rolled farthest down stream, that, whereas the flooring was practically undamaged, the wind and portal bracing had collapsed to such an extent that the two top booms were actually touching each other at one point.

Hence the top booms of all the spans suffered more than the bottom booms. Indeed, several pieces of the latter had suffered so little that they might have been put back into position without any work being done on them, except that in the process of rolling along the boulders forming the river bed, the edges of the flange plates had been very badly frayed and cut.

After a careful examination of all the spans, the Chief Engineer decided to salve, cut up and recondition spans 2, 5 and 6. As much as possible of spans 3 and 4 was to be salved, but as these spans were considered to be damaged beyond repair, it was decided to replace them with two new spans from England.

It was also decided to raise the height of the piers twenty feet, in order to ensure that the girders would be well clear of the water, should a repetition of such a remarkably high flood take place.

Arrangements were at once made to construct a pontoon bridge to enable passengers to be transhipped until such time as through running could be resumed by means of a diversion and pile bridge.

The pontoon bridge was nine hundred feet long, and it was opened to Traffic on the 14th of November, or only 27 days after the decision to build it had been arrived at.

The pontoons consisted of six 45 gallon oil drums fixed in timber frames, as shown in Illustration No. 6.

There were 60 pontoons spaced 15 feet apart, centre to centre.

The decking consisted of bamboo "challis", covered with gunny bags loosely filled with sand.

The sand filling was found to be unsatisfactory, as it had a tendency to become pressed out towards the sides of the decking, and also wore away the bags very quickly. Straw filling was afterwards tried with much better results.

While the time taken to complete this pontoon bridge is possibly not a record when compared with some of the achievements of the Great War, the speed at which it was designed, built, transported (including transhipment) and erected must rank high amongst the Engineering efforts of India.

The diversion was 8,000 feet long, with a ruling grade of 1 in 35.

The pile bridge consisted of thirteen 40 foot spans during the season 1926-27, but was extended by two 20 foot and two 30 foot spans for the following season. The girders were carried on timber pile piers, as shown in Illustration No. 7.

The pile driving was done first with a 15 cwt. drop tup operated by a steam winch, but afterwards with a steam pile hammer fed by a Cochran boiler.

The pile driving pontoon, consisting of 130 oil drums yoked into a timber frame, was built at site. It was a successful pontoon in so much as it only drew 2′—4″ of water under full load, but it rolled so badly under the action of the drop tup, that heavy bullie legs, fitted with palms, had to be lashed vertically to the fore end, as shown in Illustration No. 8. Thus the pontoon actually stood on the bottom while a pile was being driven.

Five of the pile piers on the Gondia side of the river stood in water too shallow to float the pontoon, and these piles were driven from a pile frame mounted on a form of gantry track, supported on sleeper cribs, as shown in Illustration No. 9. By means of this arrangement the piles could be very accurately sited, and the frame moved rapidly from place to place. As many as twenty piles were driven in one day.

The Gondia bank of the river consists of sand, while the bed on the right bank, where the current is strongest, is of boulders. On the former side, piles were driven to 15 feet penetration with ease, while an average of 9′—6″ was all that could be obtained on the latter side. It is a remarkable fact that the piles having 15 feet penetration were washed out on two successive occasions, although no scour took place in their vicinity. The piles having 9′—6″ (and less) penetration are still standing, thus leading one to the conclusion that the ability of a pile to withstand displacement depends more on the nature of the bed than on the amount of penetration.

In order to facilitate the erection of the 40 and 20 foot girders, a special rocker crane mounted on a bogie truck was designed and built for the purpose from scrap material at site. This is shown in Illustration No. 10.

Each span was erected and sleepered and the rails laid, on the bank, and by means of the crane, the complete spans were lifted, carried out, and placed in position intact. Thus the

fifteen girders were erected, sleepers laid, and the line linked in four days. They were afterwards similarly dismantled in two days.

Meanwhile the salvage of the wrecked spans was progressing. In this work many unexpected difficulties were met with.

No. 2 span, for instance, was very thickly matted with a great quantity of brushwood and tree trunks, and the removal of this debris by means of axes and hand saws was a very slow and tedious process.

It is considered possible that, but for this floating debris, the whole bridge might have withstood the flood, as actually happened in the case of No. 1 span, which was topped by the flood to the same extent as the others, but on which, owing to its position, no debris accumulated.

While cutting up the broken spans, several men received minor injuries by their neglecting to bolt up a member before cutting the last rivet, thus allowing the strained members to spring violently apart when suddenly released.

Nos. 2, 3 and 4 spans were deeply buried in sand, and when an effort was made to remove this, water was met with at a depth of 2′—6″, and it was found impossible to keep the excavations dry.

These spans were therefore jacked out of the sand by timber and rail clusters placed through the bracings, the sand being removed as the spans rose. Four one hundred ton jacks were necessary on each span.

The difficulty with this arrangement was to prevent the men creating further damage by excessive straining on the jacks.

A curious instance of this was encountered in the case of No. 6 span.

In this case, the span had simply been pushed off the piers, and had landed right side up, with one end resting on the bank, and the other in about 16 feet of water. The span lay at an angle of about 30 degrees, and was remarkably little damaged, as may be seen from Illustration No. 5.

The land end was first dismantled, leaving a portion weighing 50 to 60 tons in the water. Boulder piers were built along each side of this, and an attempt made to jack it from the piers by means of a beam consisting of two 16″ × 16″ timbers.

Two fifty ton jacks, however, failed to raise the span, and finally two 150 ton and four 100 ton jacks were tried. These broke the timbers, but failed to raise the span.

The water at this point was flowing at a speed of 8 miles per hour, and it was at considerable risk that a diver finally went down to investigate.

It was then found that a very large tree had, in some extraordinary manner, passed through the bracings of the girders, precisely in the manner of the jacking beams. The ends of the tree had been unknowingly covered by the boulder piers on which were the jacks, as shown in Illustration No. 11. Hence we were, in effect, trying to lift ourselves like the man who placed a foot in each of two buckets, and tried to lift himself. The upstream boulder pier had therefore to be extended in order to protect the divers, two of whom then went down and cut the tree with hand saws.

The most difficult span to salve was No. 5.

This span had fallen on its side athwart the current, which here also flowed at 8 miles per hour. The span, which is shown in Illustration No. 4, lay at a small angle, one half of the underside girder being submerged.

It was obvious that the first thing to do was to reduce the current flowing against the span, and for this purpose a groin of boulders was built out from the bank up stream of the span. The position of the groin is indicated in Illustration No. 1.

It was soon found, however, that boulders dumped off the end of the groin were being carried away, and were probably being banked against the span. The only effect of the groin had been to concentrate the current as in a nozzle.

The remedy appeared to completely divert the stream by converting the groin into a dam.

No more boulders were available from that side on which the groin had been built, so the dam was commenced from the other side, boulders being taken from the channel into which it was intended to divert the stream.

As the new groin approached the old, it was found that the boulders were being carried away. Gunny bags were therefore filled with boulders, and dumped, and when these also began to carry away, the filled bags were tied together with wire. Eventually, when the gap had been reduced to about 15 feet, it was found that as many as seven bags tied together were carried away before they reached the bottom.

By this time the water stood 2′—9″ higher on the upstream than on the down stream side of the dam, and the water roared through the gap with a velocity which left little hope of it ever being closed.

The following arrangements, however, were made :—

First, three 30 foot rails were laid across the gap, in the manner of a bridge. Two wires, whose lengths were approximately equal to the length of the cross-sectional outline of the dam, were then made fast at each end of the rails. The centre rail was

tied at the centre of the wire, and the outer rails to the ends of the wire.

The length of the down stream slope of the dam being known, a number of wires of this length were then tied to the down stream and the centre rail, at a distance of one foot apart for the full length of the rails.

This done, the upstream rail was pushed overboard, and allowed to roll down the slopes of the dam, when the down stream rail was also pushed into the water. The wires connecting the down stream and centre rails immediately tightened up, thus forming a grid of taut wires all across the gap, as shown in Illustration No. 12.

Bags of boulders were then rapidly thrown into the gap. These were held up by the wires on the down stream side, and eventually the gap was thus closed.

The span now lay in dead water, and its salvage was taken in hand.

This was accomplished by placing a pair of the old bearings from the piers under the span at the centre, and pulling down the high end by means of winches until the submerged end rose clear of the water. The whole weight of the span was thus carried on the bearings, which acted as a fulcrum, at which points the boom pieces were badly crumpled. This sacrifice was considered worth while, however, in view of the expensive piling and timbering, and loss of time which would have otherwise been necessary to lift the span out of the water.

Each part of each span was marked as it was cut out, and each span was marked with a distinctive colour.

This marking was very troublesome, since the spans had apparently been built before the designing of details became a fine art. In each span there were over 200 small packing pieces of all shapes and thicknesses, none of which were interchangeable, and all of which had to be marked.

Incidentally, this bad detailing was the cause of considerable trouble in the re-erection of the spans. For instance, each panel point contained rivets which passed through the cross girder cleats, two diagonals, one packing, the boom plates and the post flanges. There were also countersunk rivets which passed through the post and boom plates only which had to be put in before the diagonals and packings, etc., could be erected. The objection to putting in rivets before a span is completely erected is well known.

An attempt was made to use pneumatic rivet busters in the dismantling of the spans, but although these machines did excellent service in cutting up individual pieces after they had been lowered to the ground, they were found to be much too heavy and unwieldy for use on the flimsy and unsteady scaffolding.

While the salvage work was in progress, the masonry work necessary to raise the piers 20 feet was being carried out.

The old copings and the remains of the old bed stones were dismantled. The latter were sandstone blocks from a quarry in Jubbulpore, and it is perhaps worth mentioning that most of them were found to have weathered and deteriorated to a somewhat alarming extent.

The masonry in the extensions of the piers consisted of black granite, quarried locally, laid in cement mortar of the proportions of one cement to five sand.

The cement used was of Indian manufacture, and proved most satisfactory throughout. Indian cement was also used in the reinforced copings and bed blocks, and so satisfactory were the results obtained in all cases, that the prejudice in which Indian cement is sometimes held, is difficult to understand.

As an instance of the good quality of the cement used, a temporary foundation for a staging was built in the river bed. It was built of random rubble stone in cement mortar, one to five.

Six months afterwards, it was necessary to dismantle this foundation, and it was then found that, so hard had the cement become, that the stones were broken much more frequently than the joints in the process of demolition.

The workmen and materials were carried out to the piers from the bank by means of an aerial ropeway.

Except for the steam winch by which it was operated the entire ropeway was manufactured from scrap material at the site. It extended from bank to bank, and was supported on each pier. Details of its construction are shown in Illustration No. 13.

It required considerable persuasion and much jocular conversation to induce the first man to go out in the cradle, but so powerful is the moral effect of familiarity, that eventually sentries had to be posted at each end of the bridge in order to prevent more than four men climbing into the cradle at one time.

Water for the masonry was carried by means of an inch and a half pipe slung on hooks suspended on a 2¼ inch wire stretched across the tops of the ropeway trestles. The air valves which were necessary in the pipe line at every trestle were manufactured from standard pipe fittings and small India rubber balls purchased locally. These are shown in Illustration No. 14.

No. 1 span (the only one not washed off the piers) was jacked up 3′—6″ at a time as the masonry on the abutment and pier No. 1 proceeded. Four 100-ton Hydraulic Jacks were used for this work.

The original design of the falsework on which the reconditioned spans were built consisted (in the 150 foot span) of one sixty foot and one eighty foot broad gauge plate girder span, supported at

the centre by a staging, and (in the 200 foot spans) one 33 ft. span in the centre supported on two stagings, with an 80 foot span on either side.

The plate girders were braced with timber, and carried 12 × 12 and 8 × 12 timbers, 35 feet long laid athwart on top for the decking, camber jacks and gantries. Steel stagings strengthened with timber were erected in spans 5 and 6, and two steel stagings were manufactured out of old cross girders, rail bearers and boom angles for supporting the plate girders in span No. 4. These stagings were 70 feet high to the underside of the plate spans, and carried a maximum of 190 tons each. Illustration No. 15 shows the complete stagings in No. 4 span, and the partially dismantled stagings in No. 5 span.

On the completion of Nos. 4, 5 and 6 spans, the dismantling of the falsework was effected by suspending the plate girders to the bottom booms of the main girders. The stagings were then dismantled, and the plate girders afterwards lowered by means of tackle lashed to the main girders.

The staging foundations in No. 4 span consisted of a steel grill carried on bullie piles, and in Nos. 5 and 6 spans, the foundations were of concrete.

The type of timber and plate girder falsework described above was, however, found to be much too heavy, and took too much time to erect.

For the remaining two spans, therefore, new falsework was designed.

This consisted of light angle steel posts in 16 foot lengths, extending all across the span. In each span there were 108 posts, each built up of four 3 × 3 × ¼ angles bolted together, and braced with 3 × 3 × ¼ angles.

This staging consisted of three types of members only and was very easily and quickly erected. It is seen in Illustration No. 16.

The camber jacks used were obtained from the Eastern Bengal Railway, from the surplus stock of the famous Lower Ganges (or Hardinge) Bridge at Sara. They were used in pairs, one pair on each side of each joint. In order to prevent them creeping when they were operated, they were coupled together in pairs by means of a plate, and to prevent the plate fouling the rivets, a ring was fitted on the top of each jack, as shown in Illustration No. 14.

The actual erection of the main girders differed little from the erection of any other similar girders.

The new spans from England went together with the greatest ease, but in the case of the reconditioned spans the work was very seriously hampered by missing parts which had to be manufactured at site.

Still greater delays were occasioned, however, by the fact that many members, particularly tension members, had lengthened considerably in the process of being straightened.

This defect was corrected by cutting out a strip equal in width to the excess length of the member, and rejointing with suitable butt plates.

All riveting, reamering and drilling was done by pneumatic machinery, fed by two oil driven air compressors, one at each end of a $2\frac{1}{2}$ inch pipe which extended the full length of the bridge.

With specially trained supervision, and moderately new machines, the oil driven air compressor might doubtless give satisfaction. But on work of this nature the ideal conditions necessary are seldom, if ever, obtained, and steam plant, which will plod along under almost any conditions and the worst usage, is undoubtedly preferable.

It is a tribute to the firm who manufactured the old spans that the corresponding parts of all girders were interchangeable. This was particularly fortunate in the case of Nos. 2 and 3 spans.

Due to a strike in the Engineering Works in Calcutta, where the old spans were being reconditioned, material ceased to arrive.

Parts of Nos. 2 and 3 spans which were on hand were therefore amalgamated, and worked in to form a complete span for No. 2.

The remaining material was augmented with parts taken from the two abandoned spans and No. 3 span was thus completed. The parts taken from the abandoned spans were repaired and straightened at site.

The riveting up of the last span was completed at 6 o'clock on the morning of the 7th of July, the men working right through from 6 o'clock the previous morning without a break—a performance which surely places Indian labour in a class which compares well with that of any other country. Their efforts undoubtedly saved the B. N. Railway Company, a considerable sum of money, for the river began to rise very shortly afterwards, and the last few pieces of staging were removed with the men working knee-deep in a rising flood.

The floods having started, the bridge could not be tested by the ordinary means.

Wooden hangers supported on tight wires running the full length of the bridge and supported on each pier clear of the girders were therefore devised. These worked very satisfactorily. They are shown in Illustration No. 17.

The maximum deflection registered under the speed test, consisting of two engines coupled head to head running at 30 miles per hour, was ·85 inches, with ·25 inches oscillation.

Illustration No. 18 shows the completed bridge, the work having been carried out in 19 months from the date of starting the dismantling of the wrecked spans.

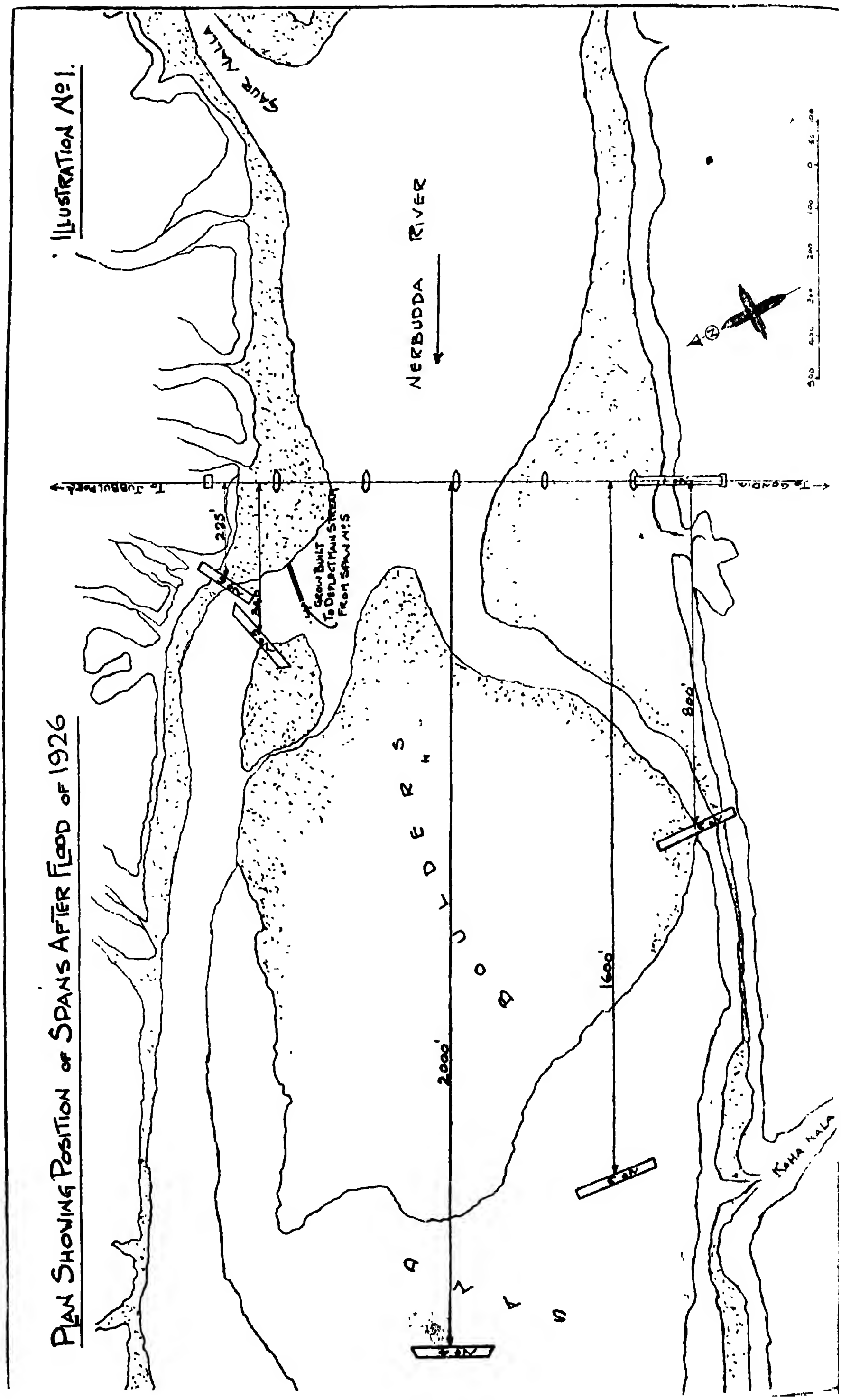


ILLUSTRATION No. 1.
PLAN SHOWING POSITION OF SPANS AFTER FLOOD OF 1926
NERBUDDA RIVER
GAUR NALLA
To JUBBULPORE
To GONDIA
225'
800'
1600'
2000'
GROYNE BUILT TO DEFLECT MAIN STREAM FROM SPAN No. 5
KAHA NALA

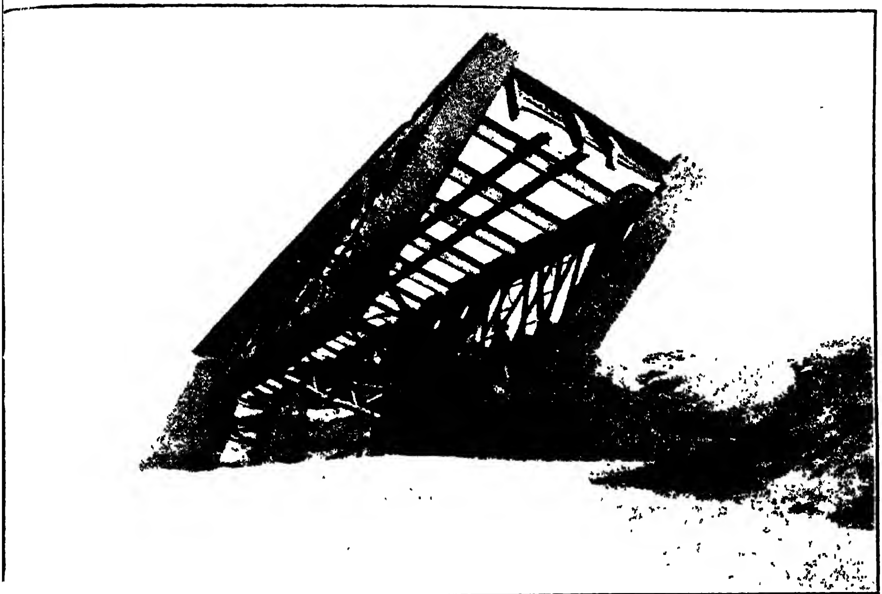


Illustration No. 2
No. 3 Span, lying bottom up.

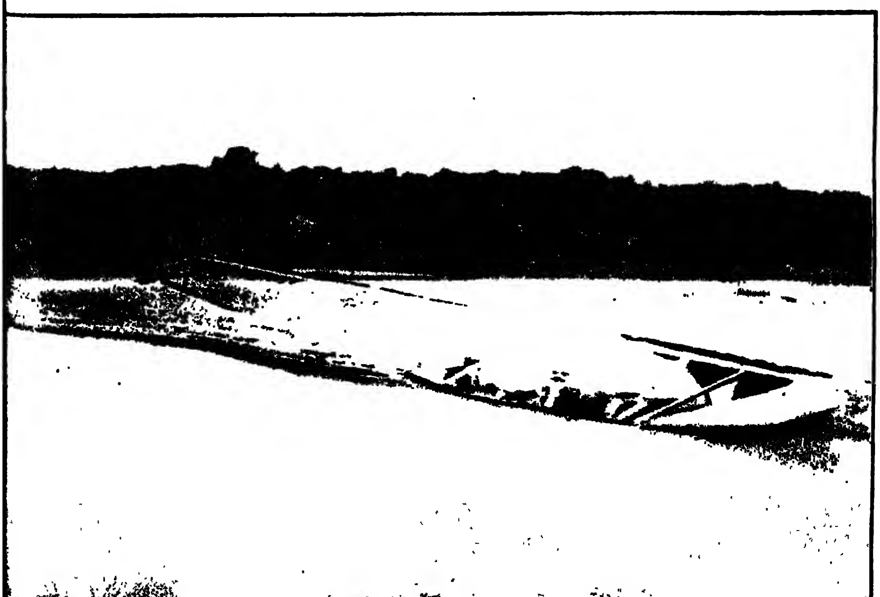


Illustration No. 3.
No. 4 Span, on its side, burried in sand.

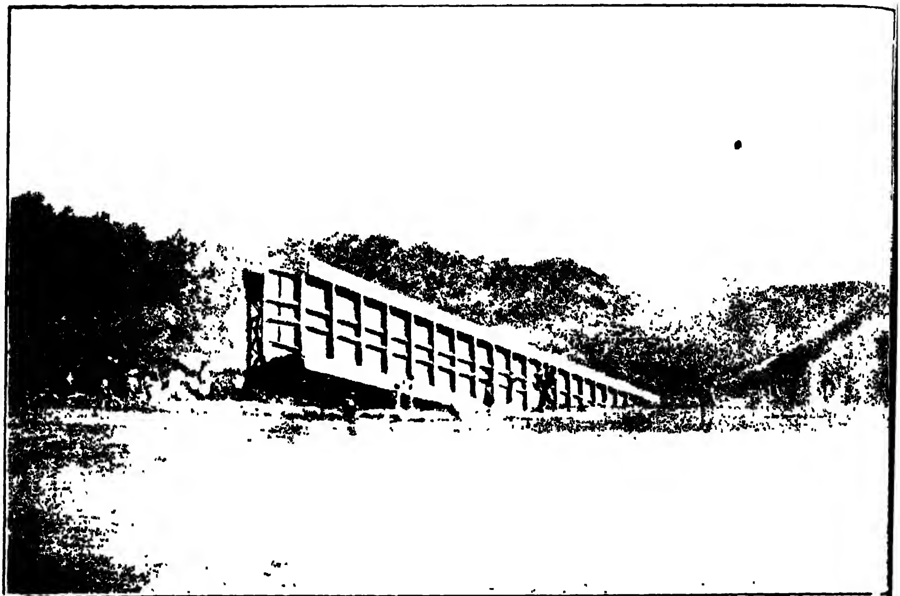


Illustration No. 4
No. 5 Span, on its side, partially submerged.

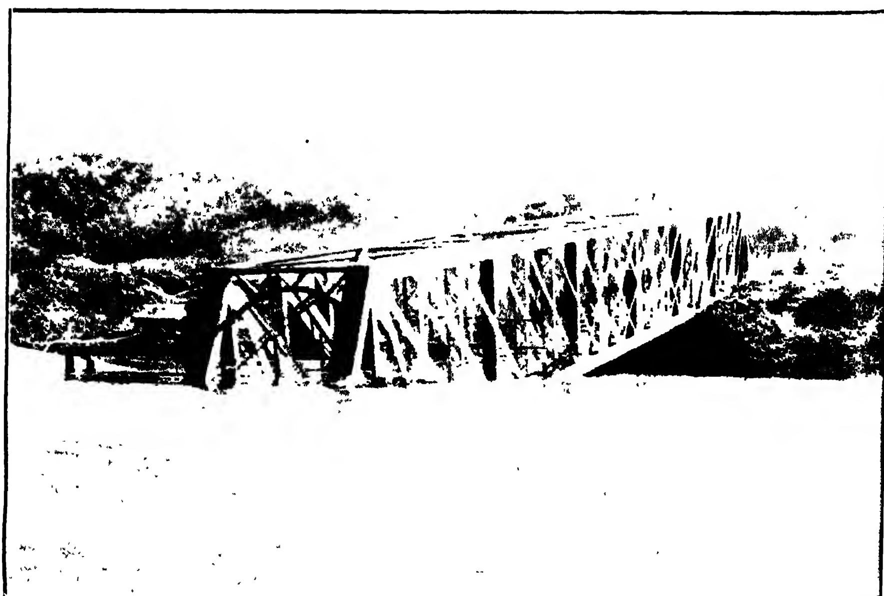


Illustration No. 5
No. 6 Span (150 feet).

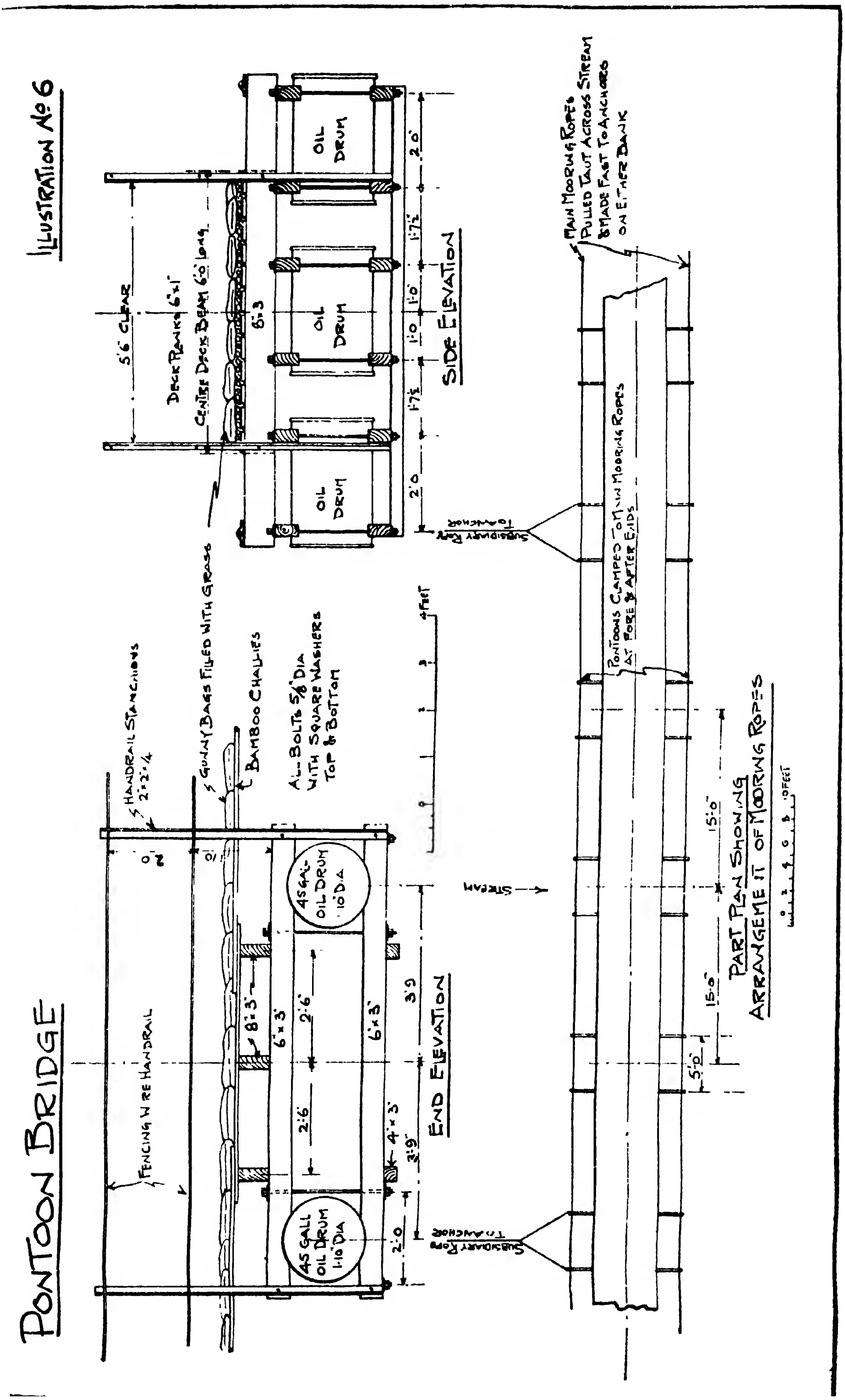
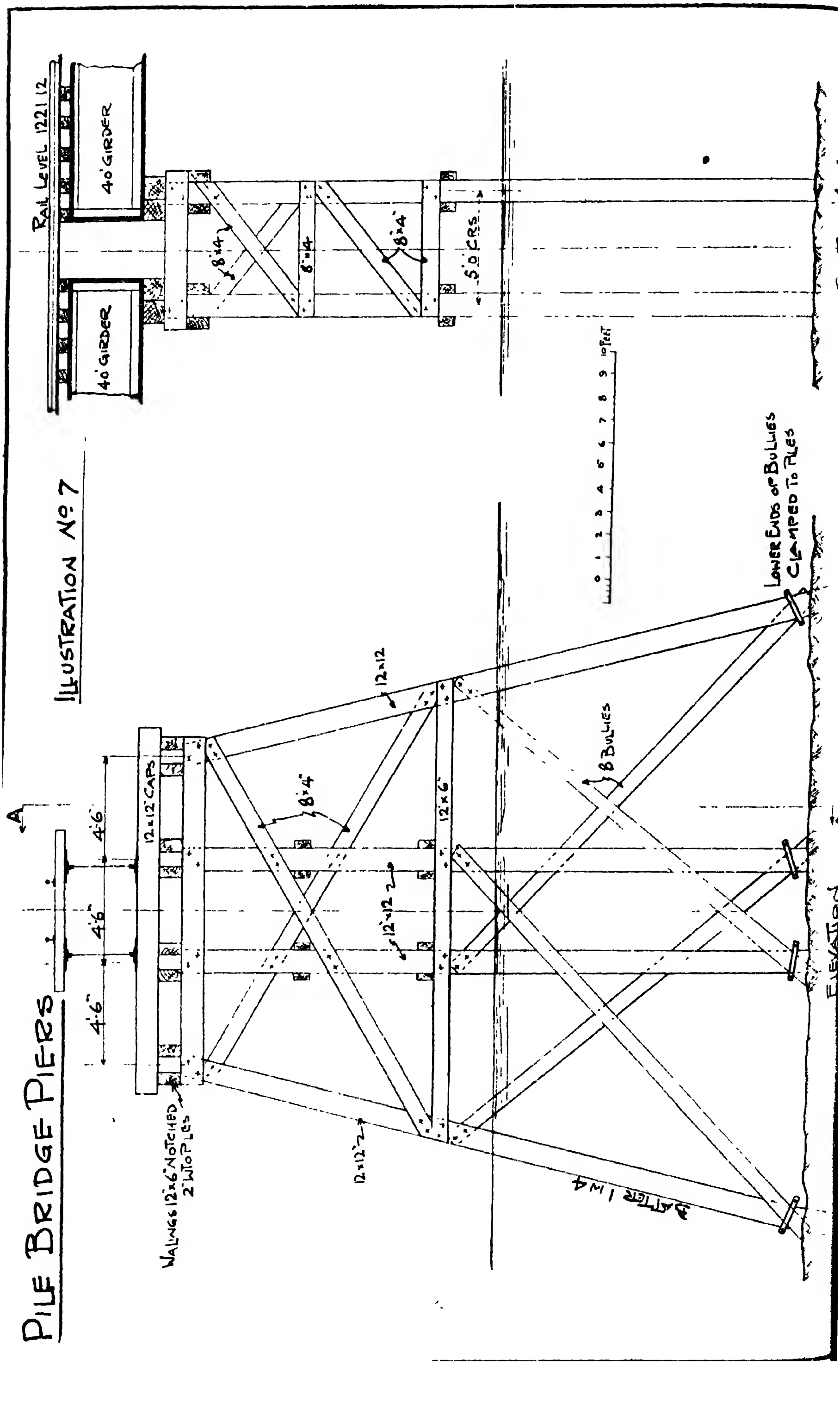


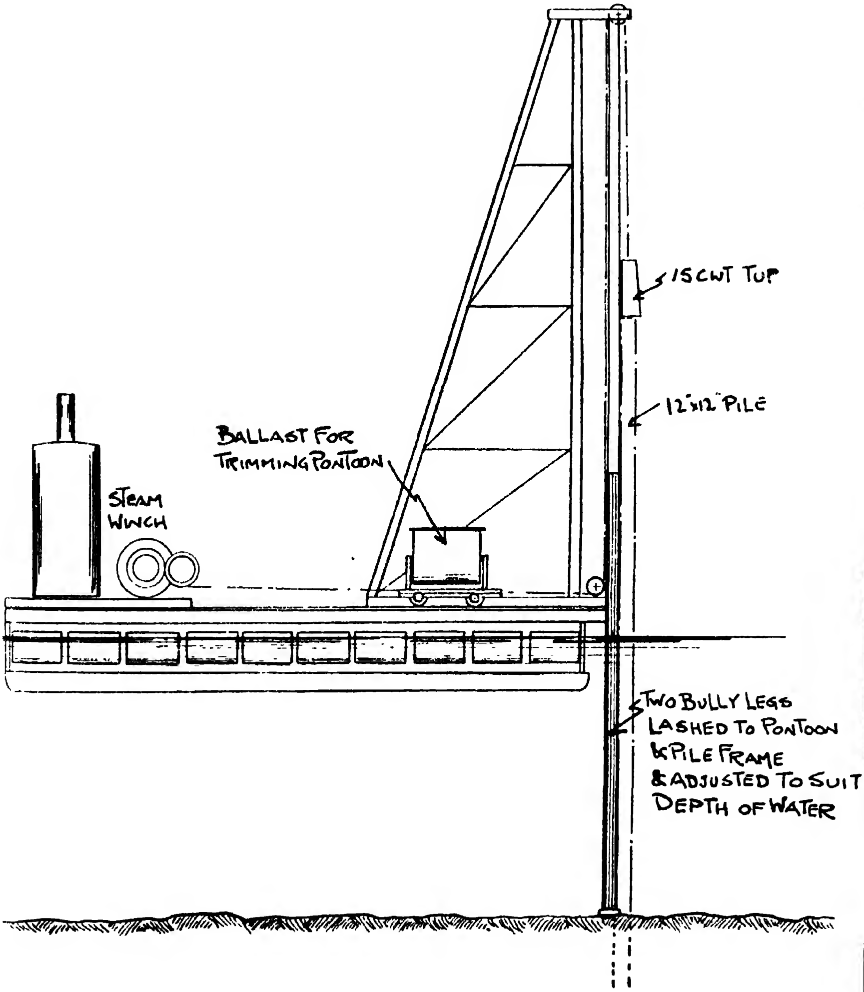
Illustration No 6
Pontoon Bridge
Side Elevation
End Elevation
Part Plan Showing Arrangement of Mooring Ropes
Main Mooring Ropes Pulled Taut Across Stream & Made Fast To Anchors On Either Bank
Pontoons Clamped To Main Mooring Ropes At Fore & After Ends
Subsidiary Rope To Anchor
Subsidiary Rope To Anchor
Stream
5'6" Clear
Deck Planks 6"x1"
Centre Deck Beam 6'0" Long
Oil Drum
Oil Drum
Oil Drum
Gunny Bags Filled With Grass
Bamboo Challies
Handrail Stanchions 2"x2"x4
Fencing Wire Handrail
All Bolts 5/8 Dia With Square Washers Top & Bottom
45 Gal Oil Drum 1'10" Dia
45 Gall Oil Drum 1'10" Dia
6"x3"
6"x3"
4"x3"
8"x3"
15'0"
15'0"
5'0"



PILE BRIDGE PIERS
ILLUSTRATION No. 7
RAIL LEVEL 1221.12
40' GIRDER
40' GIRDER
8"x4"
8"x4"
8"x4"
5'0" CRS
10 FEET
LOWER ENDS OF BULLIES CLAMPED TO PILES
12x12
8"x4"
8" BULLIES
12x6"
12"x12" CAPS
4'6"
4'6"
4'6"
12"x12"
12"x12"
WALINGS 12"x6" NOTCHED 2" INTO PILES
12"x12"
BATTER 1 IN 4
ELEVATION
A

PILE DRIVING PONTOON

ILLUSTRATION No. 8



ELEVATION

SHOWING LEGS TO PREVENT ROLLING.

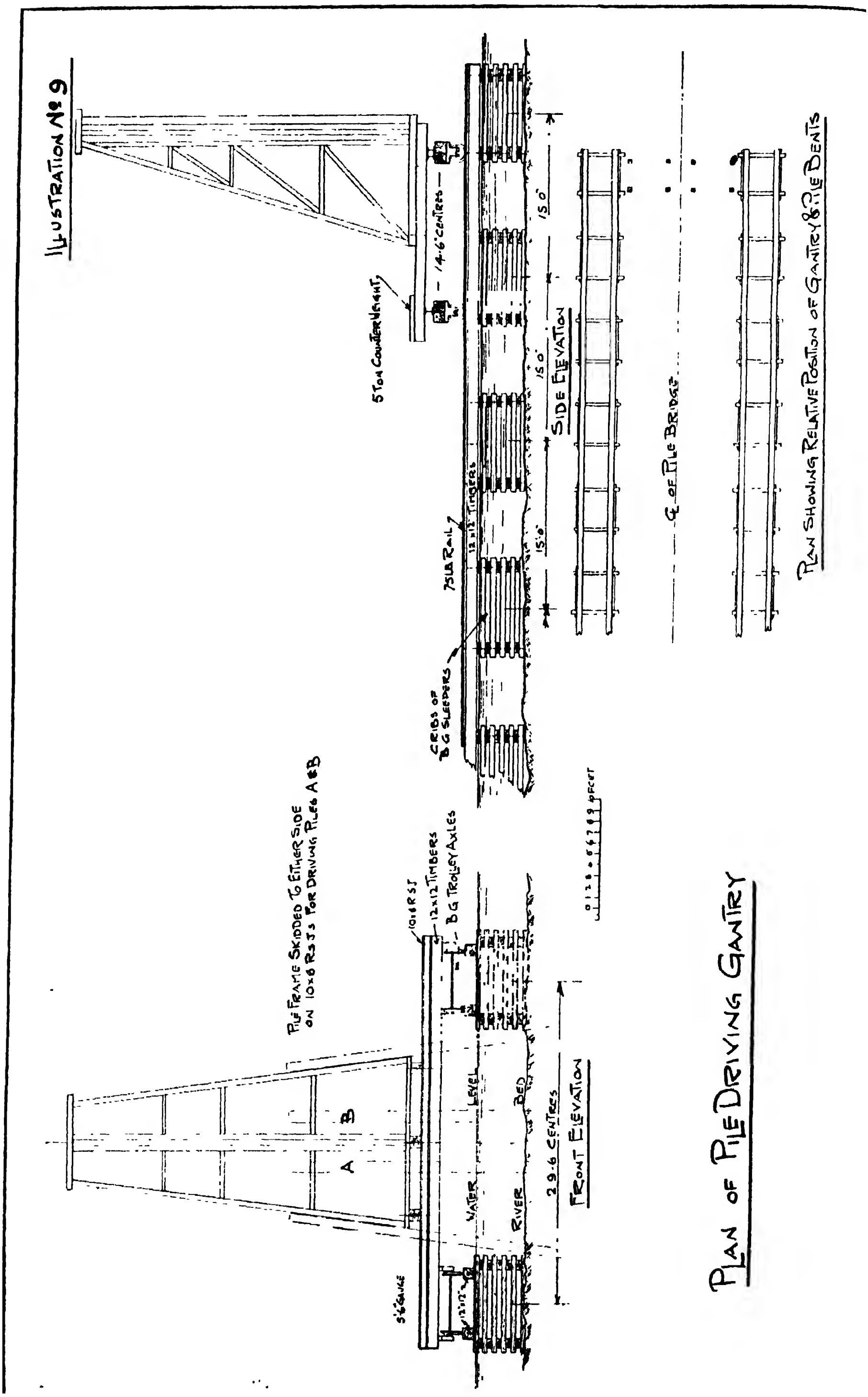


ILLUSTRATION No 9
PLAN OF PILE DRIVING GANTRY
5 TON COUNTERWEIGHT
14.6' CENTRES
75LB RAIL
12x12 TIMBERS
CRIBS OF B G SLEEPERS
15.0'
15'0'
SIDE ELEVATION
℄ OF PILE BRIDGE
PLAN SHOWING RELATIVE POSITION OF GANTRY & PILE BENTS
PILE FRAME SKIDDED TO EITHER SIDE ON 10x8 RSJs FOR DRIVING PILES A & B
10x8 RSJ
12x12 TIMBERS
B G TROLLEY AXLES
A
B
WATER LEVEL
RIVER BED
29.6 CENTRES
FRONT ELEVATION
5'6 GAUGE
FEET

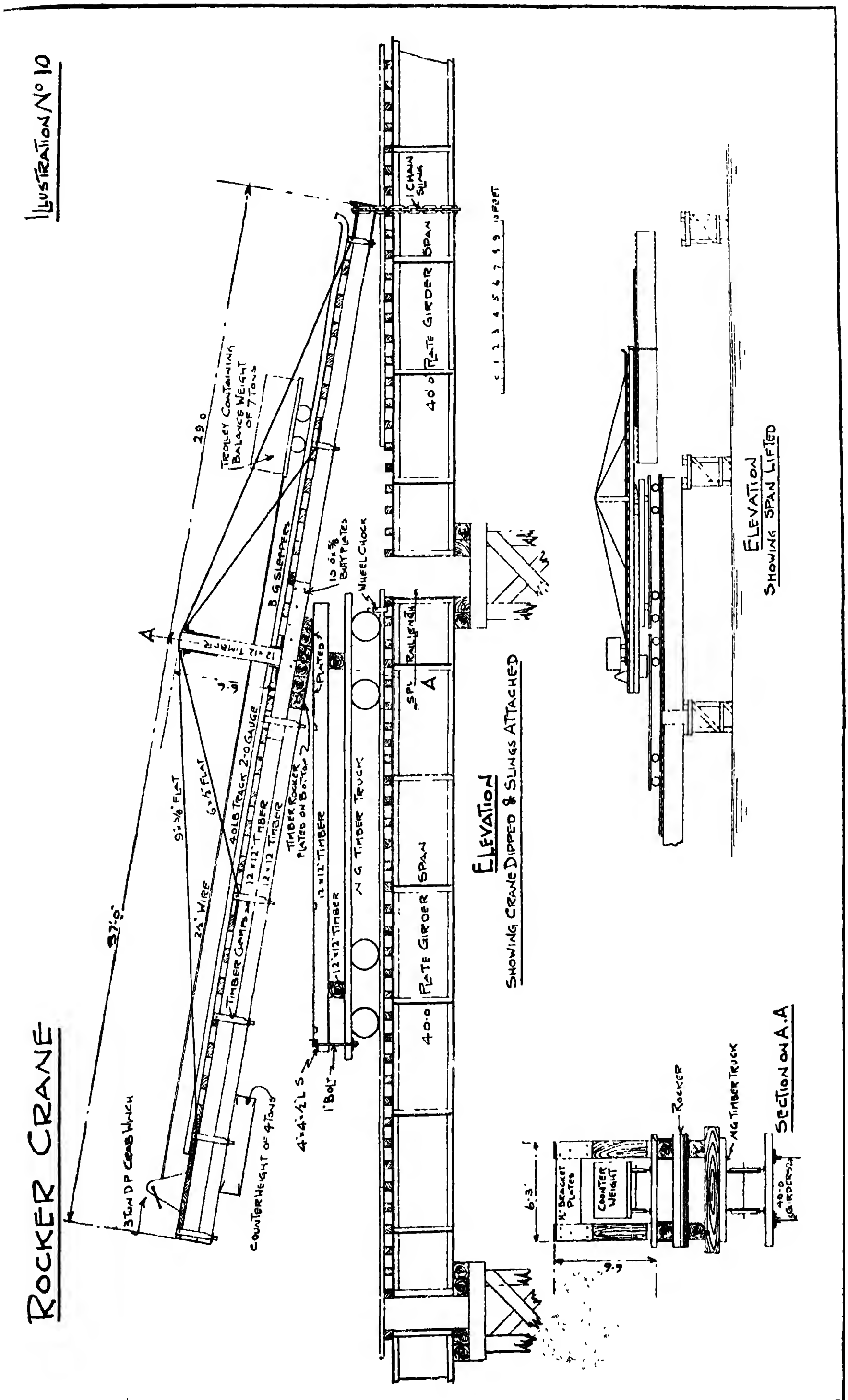


ILLUSTRATION No 10
ROCKER CRANE
ELEVATION
SHOWING CRANE DIPPED & SLINGS ATTACHED
ELEVATION
SHOWING SPAN LIFTED
SECTION ON A.A
40·0 PLATE GIRDER SPAN
TROLLEY CONTAINING BALANCE WEIGHT OF 7 TONS
COUNTER WEIGHT OF 4 TONS
B G SLEEPERS
WHEEL CHOCK
N G TIMBER TRUCK
ROCKER
COUNTER WEIGHT
29·0
37·0

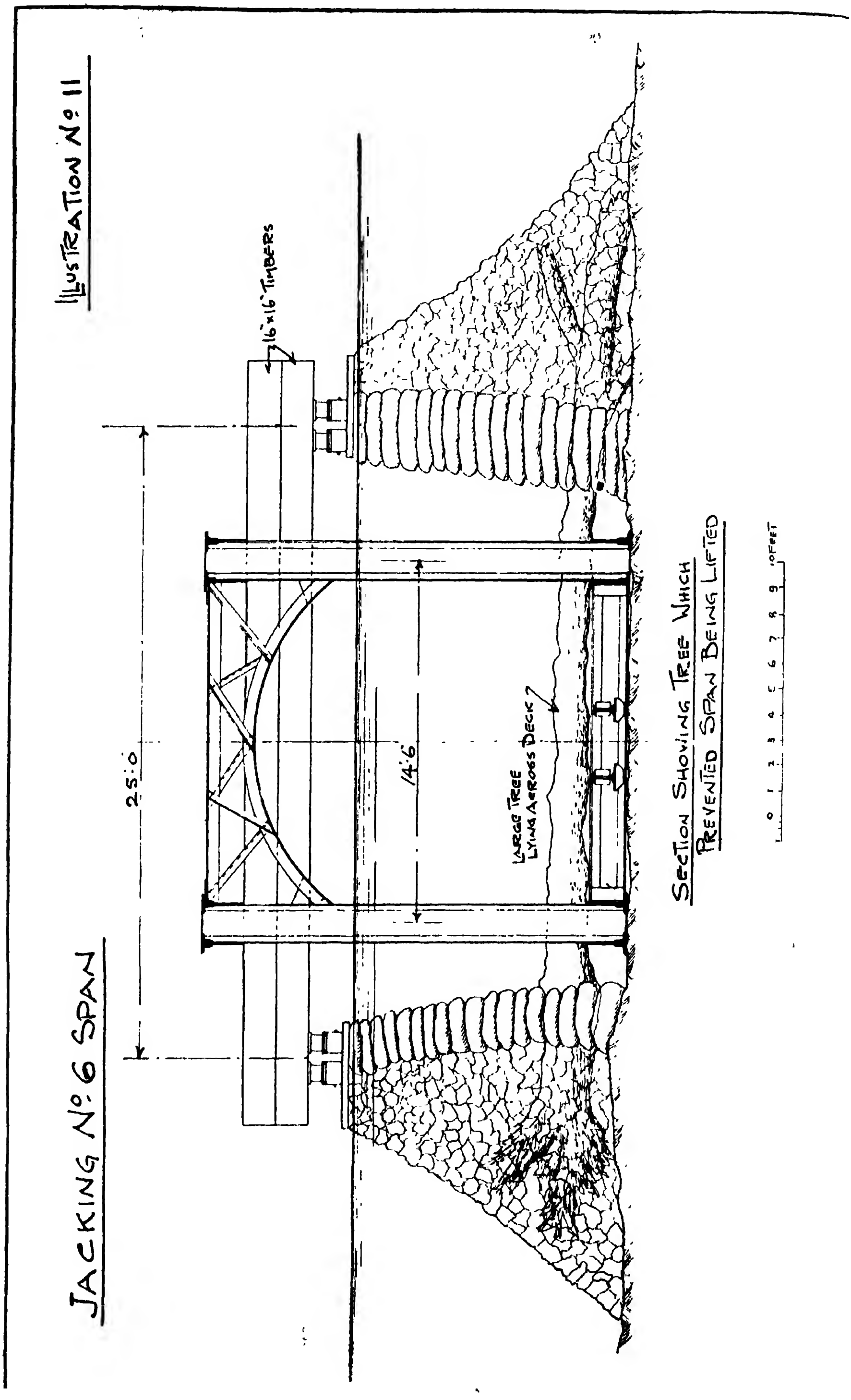
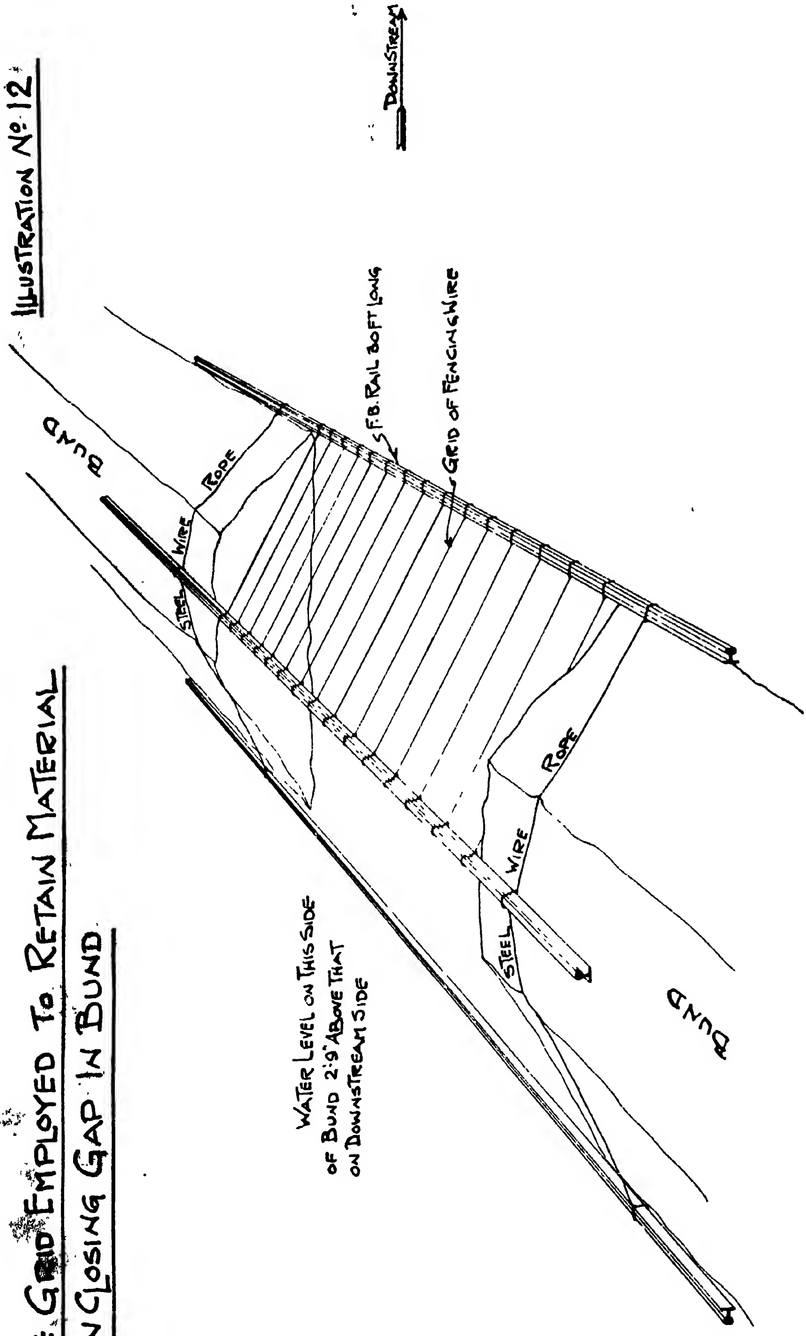
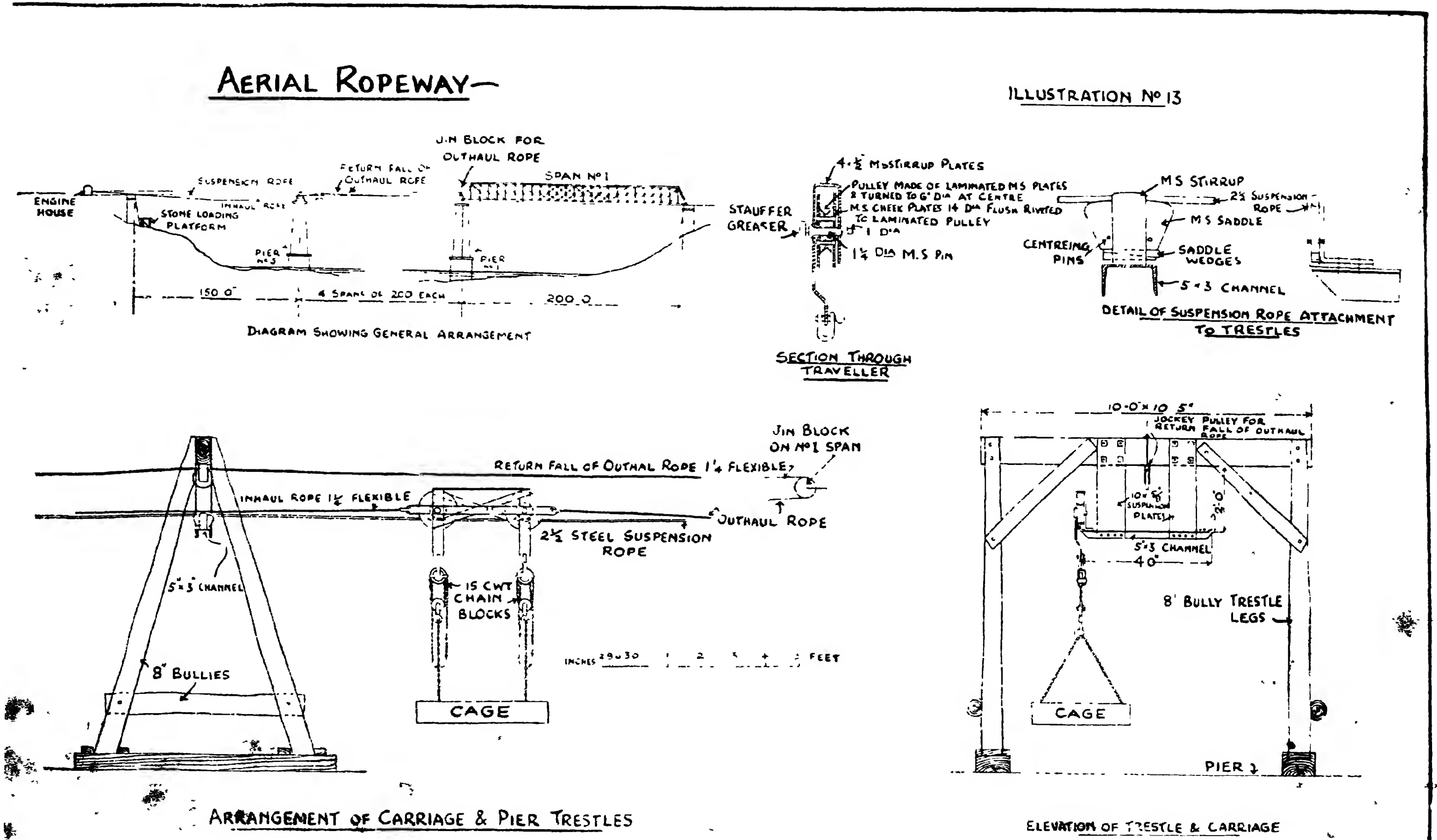


ILLUSTRATION No 11
JACKING No 6 SPAN
16"x16" TIMBERS
25'0
14'6
LARGE TREE LYING ACROSS DECK
SECTION SHOWING TREE WHICH PREVENTED SPAN BEING LIFTED
0 1 2 3 4 5 6 7 8 9 10 FEET

Illustration No. 12



Wire Grid Employed to Retain Material
When Closing Gap in Bund.


AERIAL ROPEWAY—
ILLUSTRATION No 13
ENGINE HOUSE
SUSPENSION ROPE
INHAUL ROPE
STONE LOADING PLATFORM
RETURN FALL OF OUTHAUL ROPE
J.N BLOCK FOR OUTHAUL ROPE
SPAN No 1
PIER No 5
PIER No 1
150 0"
4 SPANS OF 200 EACH
200 0
DIAGRAM SHOWING GENERAL ARRANGEMENT
4·½ MS STIRRUP PLATES
PULLEY MADE OF LAMINATED MS PLATES & TURNED TO 6" DIA AT CENTRE
M.S CHEEK PLATES 1¼ DIA FLUSH RIVETED TO LAMINATED PULLEY
1 DIA
1¼ DIA M.S PIN
STAUFFER GREASER
SECTION THROUGH TRAVELLER
M S STIRRUP
2½ SUSPENSION ROPE
M S SADDLE
CENTREING PINS
SADDLE WEDGES
5 × 3 CHANNEL
DETAIL OF SUSPENSION ROPE ATTACHMENT TO TRESTLES
JIN BLOCK ON No 1 SPAN
RETURN FALL OF OUTHAL ROPE 1¼ FLEXIBLE
INHAUL ROPE 1¼ FLEXIBLE
OUTHAUL ROPE
2½ STEEL SUSPENSION ROPE
5"×3 CHANNEL
15 CWT CHAIN BLOCKS
8" BULLIES
CAGE
INCHES 29 30 1 2 3 4 5 FEET
ARRANGEMENT OF CARRIAGE & PIER TRESTLES
10·0"×10 5"
JOCKEY PULLEY FOR RETURN FALL OF OUTHAUL ROPE
10×5 SUSPENSION PLATES
5"3 CHANNEL
4 0"
8' BULLY TRESTLE LEGS
CAGE
PIER
ELEVATION OF TRESTLE & CARRIAGE

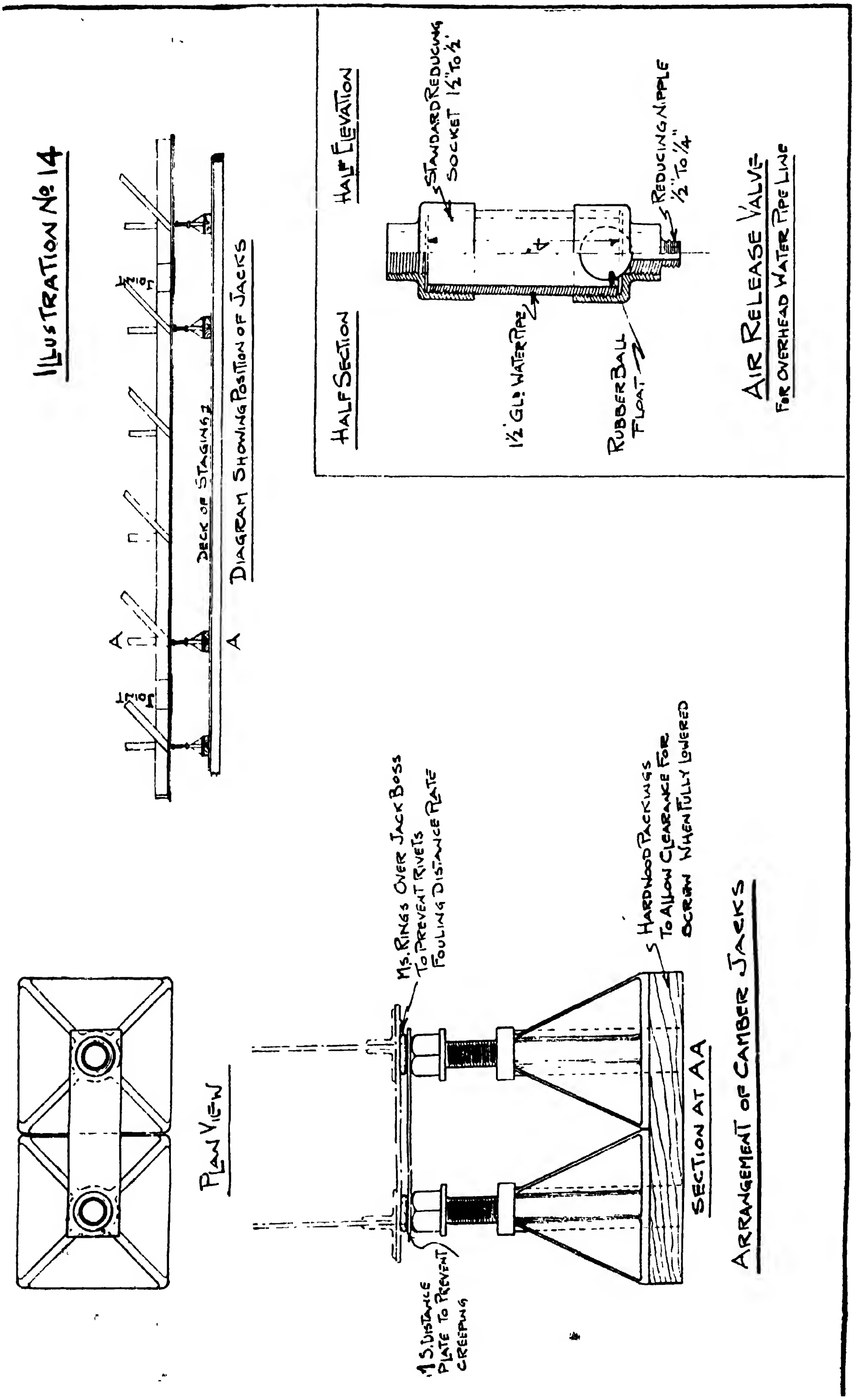


Illustration No. 14
Deck of Staging
Joint
Joint
A
A
Diagram Showing Position of Jacks
Plan View
Ms. Rings Over Jack Boss To Prevent Rivets Fouling Distance Plate
Hardwood Packings To Allow Clearance For Screw When Fully Lowered
M.S. Distance Plate to Prevent Creeping
Section at AA
Arrangement of Camber Jacks
Half Elevation
Half Section
Standard Reducing Socket 1½" to ½"
Reducing Nipple ½" to ¼"
1½" Gl. Water Pipe
Rubber Ball Float
Air Release Valve
For Overhead Water Pipe Line

DISCUSSION ON NERBUDDA BRIDGE.

Dr. A. Jardine.

Dr. A. Jardine said he would ask Mr. Stabler to illustrate by means of sketches on the Black Board a little more fully the method of application and details of testing the girders by means of the wire rope apparatus shown on illustration No. 17. Little mention was made in the context regarding the test and several points were not clear from this illustration.

With regard to the two top paragraphs on page 127 he would like Mr. Stabler to give some further information regarding the amount of lengthening which had taken place in the tension members referred to together with the actual lengths of the members concerned.

Further with regard to the correction of this extension he wanted Mr. Stabler to illustrate a little more fully the method of cutting out a strip and rejointing the member with Butt plates.

Mr. H. H. Reynolds.

Mr. H. H. Reynolds remarked that he had listened with great interest to the paper by Mr. C. I. Stabler and he was to be congratulated on the successful methods employed for salving the damaged spans. He would like to ask the author, however, if he could give some idea of the actual saving in cost effected by the salving of the damaged spans. It seemed to him that, in view of the difficulties that were met with in salving and re-conditioning spans Nos. 2, 5 and 6, the cost entailed would be, if not more, about the same as the delivery of new spans to site. He assumed that the cost of erection of the salved spans, after they were re-conditioned, was not greater than the cost of erecting the two new spans sent out from England. He asked for information on this point as he had often found it cheaper to abandon damaged material rather than to salve, re-condition and utilise it and, in the case of the bridge in question, it would be interesting to learn if there had been any saving in cost and, if so, how much.

Mr. E. E. Desbruslais.

Mr. E. E. Desbruslais said that the paper was full of very interesting details of the re-construction of the Bridge, but, if only some details had been given of the spill lengths on either side of the Bridge during the high flood and how the approaches were affected, the paper would have been invaluable to all engineers.

Mr. E. E. Desbruslais

The first consideration in bridge re-construction was the ascertaining of the cause of the abnormal rise of the river and how much the waterway allowed contributed towards this.

As the river rose to 1282 on the 19th September, 1926, against the previous highest records of 1262, a difference on height of 20′ 0″. The water passed over the top Booms by 1′ 6″, and carried away girders weighing over 250 tons half a mile down stream. It was clear that the embankment approaches must have been over topped also by nearly 20 as the main girders were 17′ 0″ in depth. No earthen embankment could stand this and if the maximum gradient - if any allowed at the Bridge site-- was 1 in 200, the spill water must have passed over the approach embankments for the length of at least 200 × 20 4,000 feet or about 4 5 of a mile on each side and the whole of this embankment would have been washed away on both sides, lines and earth together with the sleepers attached. If the country on both sides, however, was quite level and needed no embankments and the Bridge was raised 20′, at most 20′ high embankments would be required on both sides. Even if the embankment of the river was rocky and high above R. L. 1282 the old bridge must have connected two gorges in the rocky sides and the flood waters must have run up all along, on both sides, and flooded these gorges.

Now in the three possible conjectures - no details were given - the raising of the Bridge 20 would entail either 20′ high embankments in the first two cases and the filling in of the gorges 20′ at most.

The waterway in all these cases would after re-construction, be much less than actually required, owing to the restricted flow of the spills on either side in the first two cases and in the last case the flow round the ends of the bridge, and the free flow over the piers after the girder were carried away.

The last case, moreover, would require a rocky ridge at right angles to the river at the Bridge site for nearly a mile in length on both sides, or that the river flowed itself in a gorge with side banks over 1282. R.L. Even in this extreme case--it might be possible as the Nerbudda flowed between two long ranges of mountains— the additional waterway gained would not be enough as the body of the piers would when raised obstruct the free flow, which actually occurred when the girders were washed away.

The duration of this highest flood level would also be very important when dealing with such an abnormal flood.

It would appear that, the approaches would require culverts to pass the spill on both sides in the first two cases and the last case supposed either high table land on both banks of the river,

Mr. E. E. Desbruslais.

which if existing should have been the roadway level of the bridge in the first instance; and if not existing would imply a high ridge at right angles to the river and would require vents as well as in the first two cases to pass the spill waters.

It would be seen from his notes that the wash way or the water-way was the first-of-all consideration in re-construction and it was a great pity that nothing was said about this.

No doubt the completion of the iron way in 11 months from its demolition by the flood was a very good record indeed.

It would also have been interesting to know for a single two feet six inch gauge Bridge with girders 17′ 0″ high, whether the spacing apart of the main girders had been arrived at and with what overturning force.

The following formula showing approximately the velocity of the river showed the importance of the main girder spacing

$$W \frac{Av^2}{2g} \cdot \frac{17}{2} = 250 \times 2240 \times \frac{x}{2}$$

when A = Area of bridge face material sq. feet

W = wt of a cft. of water in lbs.

V = Velocity of river in ft. per sec.

G = Acceleration due to gravity 32.2

X = Space apart of Main Girder.

From which $v^2 = 250 \times 2240 \times \frac{x}{2} \times \frac{4g \times x}{WA \times 17}$

If A = 10% of 200 × 17 = 340 s ft.

X = 12′ v = max 32 ft. per second.

If A = 25% of 200 × 17 then v = about 11 ft. per second.

It would be seen that the velocity required to overturn the girders of 250 tons depended on the spacing apart of the girders.

On page 121 the author said that he had come to the conclusion that "the ability of a pile to withstand displacement depended more on the nature of the bed than on the amount of penetration."

The word displacement here was evidently meant removal through material being washed away all round.

The word displacement which depended on penetration was really the bearing power of a pile; hence the confusion.

Proportion of Cement and Sand.

A one cement and 5 sand after 6 months to be as hard as stone actually, was indeed wonderful as in buildings and in reinforced work 1 : 3 is the largest amount allowable; and again the work was probably done where a slight current existed see page 125.

Mr. E. E. Desbruslais.

Also in a lime mortar 1 lime 2 sand the lime was 1/3 the quantity of mortar and if cement 1 : 5 was used the cement would be 1/6 the quantity of mortar.

If the Cement were to cost twice the cost of lime, then, it would come to the same thing if cement mortar or lime mortar were used.

Mr. D. H. Remfry.

MR. D. H. REMFRY said that the author was to be congratulated upon producing a very interesting paper. It was the sort of paper the Institution needed—namely one in which some interesting piece of work had been carried out presenting many problems and difficulties and wherein the paper detailed just what these were and how they were solved, what expedients had to be used and not only what was found to be the successful solution but also what was unsuccessful. Engineers learned more really from failures or where there had been failures than from successes.

The Engineering Department of the Railway were also to be congratulated on the way they tackled a very difficult problem. There were no problems in engineering more difficult than those which involved decisions regarding the abvisability or non-advisability of using a damaged structure. It needed a high degree of skill to diagnose the extent of the damage and the possibility of salvage. The Railway was to be congratulated on the way its officers had tackled the job. It had not only needed a high degree of skill, but also the exercise of a great deal of judgment and of courage in deciding exactly what to do.

Questions regarding damaged and distorted steel-work were always very difficult to decide. He remembered on one occasion having to repair a 50 ft. plate girder which had been dropped whilst it was being lifted. It was very badly bent and also twisted. Without cutting it to pieces it was difficult to get it straight again, and even if taken apart it would have been impossible to straighten the deformed web plate. It was a problem to know what to do with it. Finally he straightened it as far as possible and patched the damaged flange and put it back into the line. Some one might years hereafter be horrified to find a girder with a reverse camber in it.

It was really extraordinary what steel work would stand. This was not the first time a girder had had an accident at that bridge. When the bridge was being built in 1905 one of the girders dropped off the top of a pier. It, however, became a total loss as the girder was twisted and bent in such an extraordinary manner that nothing could be done with it. The steel was very good, as unfilled rivet holes in some plates had stretched

to three times their diameter on the one side and closed up completely on the other side without a plate tearing. Presumably the steel in these girders was of equally good quality. Mr. D. H. Remfry.

One feature which was interesting to note was that a girder washed off a high pier in a heavy flood did not receive the damage one might expect from the fall. Another feature was the extraordinary power of a river in full flood which could move a span weighing 250 tons half a mile down stream. As a corroboration of those last two points he remembered a case in which three 60′ spans were washed off high piers and one span recovered seven miles down stream and was salved.

The Author was to be congratulated on his so-called pontoon bridge and the ingenious way he used oil drums.

The experience with sand filling in gunny bags was interesting. For some reason gunny bags would not stand handling after having been filled with earth or sand for a short time. They would stand all right for many months if unmoved and would act as pitching to guide bunds, and when used as such pitching would enable a sand embankment to weather quite considerable floods and freshets down the river, but after having been filled for three weeks the gunny bags seemed to go to pieces if handled. From the Author's experience they would not stand being walked on if filled with sand, whilst straw filling enabled them to last much longer.

A most important precaution to take in all engineering work was to have ample plant or ample power. Often excess plant or excess power above that strictly calculated to get through the job within a specified time meant economy. It was a very common mistake and very false economy to skimp the plant. In the particular job under consideration very wise decisions were made. This was particularly evident in the matter of the rocker crane mounted on a bogie truck for erecting and dismantling the 40′ spans on the diversion. Some people might say was it economical to built this to erect 600 running feet of girderwork in four days and to dismantle it in two days. There was more to it than that. The very fact that one portion of the work was done with conspicuous success and despatch tended to tone up the whole job and to create a moral atmosphere which was a very valuable asset.

In all jobs having anything to do with bridge-work very great care had to be taken in watching the labour to guard it against unnecessary risk. In this particular job the risks were present and it seemed that it was fortunate that only minor injuries were received in cutting up the spans.

There was always a very dangerous risk in reamering operations in the open. When he was on the strengthening of the Damodar

Mr. D. H. Remfry.

Bridge and started work cutting out the main gusset plates of the spans and replacing them with larger gussets whilst still passing traffic it was necessary to ream out the holes using pneumatic reamers. Within a few days he had seven men down with steel splinters in their eyes. All men on reamers had to be provided with goggles and a large magnet was kept on the bridge to extract steel splinters out of any one's eye. Reamering holes in windy weather was particularly dangerous. Cutting out rivets was also very dangerous if care was not taken to prevent the rivet heads flying. Many men have been killed by flying rivet heads.

In Engineering work a great deal of ingenuity was called for to devise expedients to overcome difficulties. That bridge was no exception, and the difficulties encountered in the final closing of the stream in one branch of the river was a case in point. The manner in which this problem was finally solved was one to remember. One manner in which he had closed a similar gap had been to make a frame on each side of the gap and build up a pile of sand bags to a height and of a size which when simultaneously tipped over would meet and arch at the centre, the frames being connected together with tackle to tip at the same time. He was surprised that the method used for testing the deflection of the bridge proved so successful. He would have expected the vibration on the high piers to have shown itself in a marked degree in the tests. Personally he had noticed in tests on a bridge consisting of many spans on high piers that the land spans when tested by a train crossing the bridge from the near bank gave much better results than spans in the centre or towards the further end of the bridge. This he put down to vibration in the piers and to vibrations of one span placing the span ahead in a state in which it was particularly likely to pick up the vibration in some way. Apparently no such result was observed in this case. This was a narrow gauge bridge and the test was carried out at a speed of 30 mph., which was far higher than the critical speed for these spans, and probably vibrations would have been much more marked at 18 or 20 mph.

The Author was to be congratulated on a very good piece of work.

DEFLECTION AND OSCILLATION TEST.

The Author.

THE AUTHOR in reply said, the usual method adopted for testing the deflection and oscillation of a girder was to attach a pencil to the girder at the point at which the movements were required to be known, and to attach the test card to a pole or derrick erected in a suitable position in the river bed beneath the girder. The card was arranged in such a manner that it was in contact

with the pencil point so that any movement of the girder was recorded on the card. The Author.

That simple, but nevertheless quite accurate method could not be employed if the river happened to be in flood which was the difficulty he was up against at Nerbudda.

There were of course, other and more up-to-date methods of bridge testing, notably by means of the MacFadden's Deflectoscillograph.

That instrument, however, was not applicable to the Nerbudda Bridge for the following reasons:—

The Senior Government Inspector had expressed his desire to have all the spans except one, tested for deflection and oscillation at the top and bottom quarter and mid points in each girder of each span.

The necessity for such an unusually thorough and searching test was obvious when it was remembered that the reconstructed bridge consisted of—

(*a*) One span which, though it had not been washed off the piers, had nevertheless been covered by the flood and might conceivably have suffered wrecking strains, the results of which were not apparent to the eye.

(*b*) Three spans, the material of which had been bent and distorted by stresses of an unknown extent, and which had subsequently been straightened out and rebuilt. The vicissitudes through which the material had passed rendered it unwise to assume the safety of any of these spans by inference from the results of tests made on only one of them.

(*c*) Two new spans, one at least of which, would have to be tested in any case.

Thus 6 of the 7 spans were to be tested in 12 places each, or in 72 places throughout the bridge. Since only 6 Deflectoscillographs were available for the work, it followed that if they were to be used, the testing was going to occupy several days. This time could not be spared either by the Senior Government Inspector, or by the Railway; and, so it became necessary to evolve some means by which the whole bridge could be tested simultaneously. The arrangements, shewn in illustration No 17, were the result. The devices, of which there were 4 types, were all the same in principle and the following detailed description of the type for testing the bottom boom deflection would suffice to indicate the design of the other three types, *viz.*, top boom oscillation, bottom boom oscillation and top boom deflection.

The Author. Referring to the appended sketch :—

A was the bottom boom of the girder;

B was a board clamped to the boom;

C was a bridge testing card (*See* illustration No. 17 in Text);

D was a small toothed wheel which rolled on the card and marked the movement of the girder.

E was a short length of one quarter inch iron rod. At one end of the rod was the wheel D. The other end of the rod was attached to the wooden arm F. The connection of the rod to the wooden arm F was such that the rod could be pivotted vertically. This was simply to facilitate the placing of the wheel on the correct place on the card.

The arm F was connected to a vertical leg G. The arm F could be pivotted vertically and it could also be moved backwards and forwards by means of the slot H.

J was a hook formed by two 1/8″ inch plates with a piece of wood between them. The hook J was screwed to the vertical leg G.

K was a 2½″ wire stretched as tight as possible and anchored on the banks on each side of the river. The wire was supported on trestles on the piers and was not allowed to touch the girder at any point.

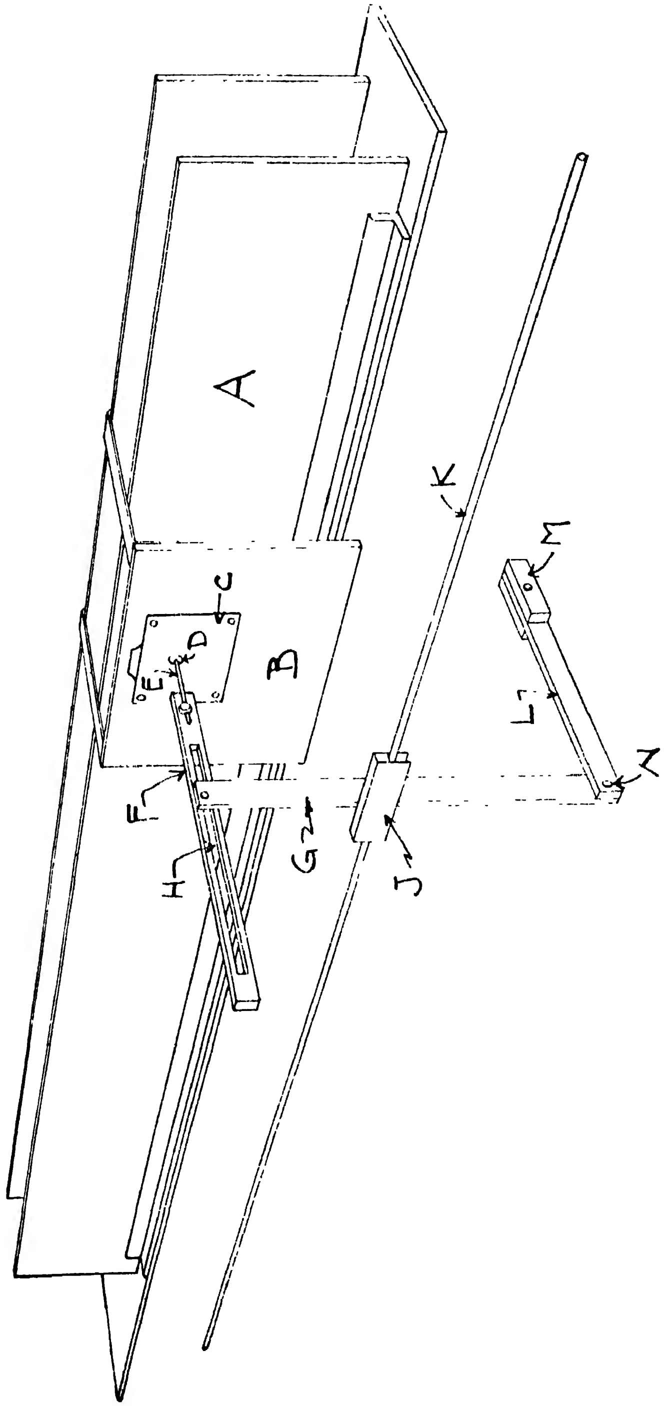
L was an arm with a small counter weight M at one end. L was pivotted at the point N, and by moving L through a vertical arc, the pressure of the wheel D on the card might be regulated.

As would be seen, the accuracy of the arrangement depended on the steadiness of the wire rope. This of course, was its great weakness, for very little disturbance was necessary to make a wire rope vibrate, no matter how tight it was pulled. Also, as Mr. Remfry had pointed out, vibration carried through the piers on which the wire was supported might be a source of interference.

Nevertheless, one span was tested by the devices described above and by Deflectoscillograph simultaneously, and the results registered by the home made devices varied from the results obtained by Deflectoscillograph by a maximum of .03 inches, which led to the remark in the text of the paper that they had worked satisfactorily.

DAMAGED MEMBERS.

Dr. Jardine had asked for details of the actual lengths of members.



DEVICE FOR TESTING BOTTOM BOOM DEFLECTION.

The Author. The theoretical length of the diagonal tension members was 22′—6¼″ between points of intersection.

When the straightened members were checked on their return from Calcutta, it was found that nearly all of them had lengthened. The amount of "stretch" varied and was as much as 11/16″ in some cases.

As the girders were of the double inter-section type, each tension member had a rivetted connection to the intermediate posts in the middle of each length. This could be seen in illustration No.5 in the text.

It was obvious that any shortening which was necessary had to be done on both sides of the intermediate post, otherwise the holes in the middle of the diagonal for the intermediate post connection would not have registered.

The method of shortening was as follows:—

(1) A pair of diagonals was bolted up in position. A pair, in this case, meant the two identical diagonals on either side of any three posts. Being too long, they were, of course, "sprung" or "bowed" between the points of connection.

(2) The diagonals were cut with a hack saw on either side of the intermediate post. Each diagonal was then in three separate pieces, each of approximately the same length.

(3) Timber packers previously prepared were then inserted between the diagonals. These packers were 6 to 8 ft. long and were 12 inches wide. Their thickness corresponded exactly to the correct width between the inside surfaces of the diagonals.

(4) Both diagonals were then clamped to the packer by special clamps.

(5) The diagonals then overlapped at the point where they had been cut with a hack saw. The amount of the overlap was the amount of the excess length.

(6) The amount of overlap was then marked and a strip was cut out of the diagonal equal in width to the amount of the overlap.

(7) The ends of the diagonal on each side of the points where the strip had been cut out were then drilled and rejointed with butt plates.

This was the system finally adopted and was only arrived at after several other methods had been tried and found unsatisfactory.

In reply to Mr. Reynolds he would say that reconditioning was not only cheaper but would have been considerably quicker had it not been for the unavoidable delay caused by the strike in the works of the Engineering Firms in Calcutta who had the contract for reconditioning these spans. **The Author.**

CAPACITY OF THE WATERWAY THROUGH BRIDGE.

The data on which the waterway was provided was given below:—

Catchment area above bridge	...	6000 sq. miles
Slope of bed	..	1.3′ per mile
Mean cross-section area	.	60989 sq. ft.
Discharge of the river by Mississippi Formula	.	109218 C. F. S.
Mean velocity calculated	.	17.9 ft. per second

The waterway originally provided was as follows:—

Available cross-section of bridge below girders.	..	72000 sq. ft.
Mean level of bed	.	1195 ft.
Level of bottom of girders	...	1262 ,,
Calculated high flood level	.	1254 ,,

It would, therefore be seen that the waterway originally provided was ample according to the usual methods of calculation.

The flood was due to one of those cases of excessive rain-fall which could not ordinarily be economically provided for. Adequate provision for such down-pours was manifestly impossible.

The excessive height reached by the flood at the bridge site was believed to be due, in part, to the discharging capacity of the river below the bridge being inferior to that at and above the bridge, which caused heading up and reduction of velocity at the bridge. If this was the case, no calculated velocities due to the slope and cross-section would hold good.

Regarding the approaches, neither bank suffered much. The old line approached the bridge at a grade of 1 in 100 down on both sides.

Hence the approaches must have been under water for a length of 2000 ft. during the flood, but as the line at that time ran mostly in deep rock cuttings for a considerable distance back from the bridge on either side, little damage was done beyond the washing out of the short approach banks behind the abutments.

The Author. The new banks were 20 ft. high at the abutments and were carried out level until they met the old grading. No vents (other than an occasional boulder drain, where necessary) had been provided in either bank, because, as already stated, provision for such an abnormal flood was not an economical proposition where the possible damage could only amount to the wash-out of a short length of earthen bank.

The formula for the overturning moment of a girder quoted by Mr. Desbruslais was interesting. It was, however, difficult to apply in the present case, since the items A and V were unknown.

The area A presented to the flood could not be ascertained for the reasons given in para. 4 page 122 of the text, while the velocity of the current V could not be computed due to the heading up which was believed to have taken place. From his formula, Mr. Desbruslais deduced that :—

If A equalled 10 per cent of the area enclosed by the outline of the girder (a very reasonable figure)

and X equalled 12 ft. then the velocity required to overturn the span would be 32 ft. per second, or nearly 22 miles per hour,—a very high figure indeed.

Actually, however, the spacing of the girders X was 14 ft. which would require a still higher velocity to cause overturning.

This he thought, proved the theory stated in the text to the effect that the wash-away was due to the girders becoming matted with debris, and thus each span presented a wall 212 ft. long by 17 ft. high to the stream. Again so much brush-wood was found on each span (and they must have lost a lot in their descent to the river bed) that the flotation of the debris must have been considerable, and it was conceivable that that factor also assisted the girders off the piers.

PROPORTION OF CEMENT AND SAND.

He could not agree with Mr. Desbruslais in that there was anything wonderful in a mixture of 1 cement to 5 sand proving harder than stone. It all depended on the kind of stone.

The stones, used in the case under discussion, were boulders from the river bed. They were a mixture of black trap, quartz, sandstone and others, of which he did not know the names. He was not a geologist, but the great variety of the stone in the boulders forming the river bed always appeared to him to be astonishing.

The hardest of all appeared to be the black trap, but even that occasionally split and left chips adhering to the cement during the demolition of the foundation.

The question of the comparative cost of lime and cement raised by Mr. Desbrulais was also very interesting, and was, he thought worth a lot of consideration. The Author

Now that cement of excellent quality was manufactured in India, there must be frequent cases where a weak cement mixture would cost no more than a rich lime mixture, and would, of course be much more satisfactory.

About 4 or 5 years ago, the Bengal-Nagpur Railway built some experimental quarters at Sini. The walls were, if he remembered rightly, only 5 inches thick. They were of concrete of the proportions of 1 Indian cement to 6 sand to 12 ballast, and had no reinforcement in them whatever. Those quarters were still standing, and so far as he was aware, had cost very little in maintenance.

But the idea that cement work was expensive died hard. One read that even the Southern Railway in England, where one would expect to find advanced methods in operation, were still building their overbridge piers of brick in lime.